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INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

L BULLETIN NO. 10

INTERNATIONAL HYDROLOGICAL DECADE
DECENNIE HYDROLOGIQUE INTERNATIONALE

IFYGL

US IHD
1965 - 1974

1974

INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

YGL BULLETIN NO. 10

AY 1974

IFYGL

US IHD

1965 - 1974

UNITED STATES

DEPARTMENT OF COMMERCE

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DEPARTMENT OF ENERGY, MINES AND RESOURCES

ONTARIO MINISTRY OF THE ENVIRONMENT

ONTARIO MINISTRY OF NATURAL RESOURCES

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CANADA

Editor	Brian O'Donnell
Typist	Joan Atkinson

INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

AES FILE: 8720-11 (ACHC)

Canadian IFYGL Centre - ACHC
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario
M3H 5T4
February 18, 1974

TO: IFYGL Steering Committee
IFYGL Joint Management Team
IFYGL Panel Co-chairmen
Canadian IFYGL Project Leaders

SUBJECT: IFYGL Centre Moved to AES, Downsview (Toronto)

Please be advised that, effective immediately, the Canadian IFYGL Centre will be located at the Atmospheric Environment Service Headquarters, Downsview, (Toronto), Ontario. Correspondence should be addressed to Mr. B.J. O'Donnell as Canadian Coordinator, or myself as Canadian Co-chairman of the Steering Committee and Joint Management Team, c/o:

Canadian IFYGL Centre, - ACHC
Atmospheric Environment Service
Environment Canada
4905 Dufferin Street
Downsview, Ontario
M3H 5T4

Telephone numbers are:

B.J. O'Donnell, (416) 667-4955
T.L. Richards, (416) 667-4617.

This move comes as a result of the recent resignation of Mrs. A. O'Hara, long-time secretary for the Canadian IFYGL Centre, CCIW, Burlington. In subsequent discussions with Mr. J.P. Bruce, Director, CCIW, it was agreed that, since both Brian O'Donnell and I were at AES Headquarters, it would be more efficient to move the Centre to Downsview (Toronto).

Please note that the Canadian IFYGL Data Centre remains at CCIW, Burlington.

Yours sincerely,

T. L. Richards

T.L. Richards
Canadian Co-chairman
IFYGL Steering Committee and
IFYGL Joint Management Team

INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES

IFYGL

IHD 1965 1974

STEERING COMMITTEE
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Cdn.- J. MacDowall

AES File: 8720-11 (ACHC)

ATMOSPHERIC ENVIRONMENT SERVICE
4905 Dufferin Street
DOWNSVIEW, Ontario
M3H 5T4

February 28, 1974

Mrs. Alix O'Hara
44 Maplewood Avenue
HAMILTON, Ontario
L8M 1W5

Dear Alix:

On behalf of the Canadian members of the IFYGL Steering Committee and Joint Management Team, I would like to express our gratitude for your efforts in support of the Field Year. Those of us who have had occasion to work directly with you could always sense both your sincere interest and loyalty to IFYGL.

I am certain that your memories of the Field Year will go beyond the many hours that you have spent grinding out minutes and Bulletins. In the past, as others have moved on, you have provided a most valuable link, a corner-stone which will be truly missed.

Once again, thank you for a job well done and all the best in your new position. I am sure that your new employer will benefit, as we did from your hard work and pleasant nature.

Yours sincerely,

T. L. Richards

T.L. Richards
Canadian Co-chairman
IFYGL Steering Committee
and Joint Management Team

CANADIAN PROJECT REPORTS

Note: 1. Projects are numbered consecutively.

2. The letters following the number indicate which Panel has prime responsibility for the project:

BC - Biological-Chemical
BL - Boundary Layer
EB - Energy Budget
ME - Lake Meteorology and Evaporation
TW - Terrestrial Water Balance
WM - Water Movement
F - Feasibility

Project

1F: *Remote Sensing*

Principal Investigator: K.P.B. Thompson - CCIW

This project is complete and has been reported on in the following publications:

(1) Thomson, K.P.B. 1973. High Altitude Remote Sensing Surveys of Lake Ontario. IFYGL Bulletin No. 8.

(2) Bukata, R.P. and W.D. McColl. 1973. The Utilization of Sun-Glint in a Study of Lake Dynamics. Proceedings of the AWRA Symposium on Remote Sensing and Water Resources Management, 17.

3WM: *Statistical Prediction of Lake Currents*

Principal Investigator: H.S. Weiler - CCIW

Some preliminary development work has been completed, however, priorities have caused a temporary hault to project work. It is anticipated that work will re-commence in the fall of 1974.

4WM: included in Project 45WM.

5BL: *Direct Measurement of Energy Fluxes*

Principal Investigator: M. Donelan - CCIW

Reported in Bulletin #9.

8EB: *Shore-Gauging Stations of Water Temperature*

Principal Investigator: D.G. Robertson - CCIW

Data is currently on cards and is being prepared for submission to the Data Bank in April 1974. Some preliminary analyses have been completed and preparation is continuing for the publication of the results of these analyses.

9EB: included in Project 42EB.

11TW: *Monthly Water Balance of the Lake Ontario Basin*

Principal Investigator: D.F. Witherspoon - IWD Cornwall

Reported in Bulletin #9.

12TW: *Monthly Water Balance of Lake Ontario*

Principal Investigator: D.F. Witherspoon - IWD Cornwall

Reported in Bulletin #9.

13TW: *Groundwater Flow into Lake Ontario*

Principal Investigator: D.H. Lennox - DOE, Hydrology

Completed.

14TW: *Hydrology of Lake Ontario*

Principal Investigator: E.A. MacDonald - DOE, Water Survey

The data has been submitted to the Data Bank at CCIW and the project is now completed.

15BL: *Space Spectra in the Free Atmosphere*

Principal Investigators: G.A. McBean and E.G. Morrissey - AES

Reported in Bulletin #9.

16ME: *Airborne Radiation Thermometer Survey*

Principal Investigator: J.G. Irbe - AES

Completed.

18ME: *Climatological Network*

Principal Investigator: J.A.W. McCulloch

Completed.

19ME: included in Project 66ME

20ME: *Bedford Tower Program*

Principal Investigator: J.A.W. McCulloch - AES

Reported in Bulletin #9.

21ME: *Canadian Shoreline Network*

Principal Investigator: J.A.W. McCulloch - AES

Reported in Bulletin #9.

22ME: *Synoptic Studies*

Principal Investigators: J.A.W. McCulloch and M.S. Webb - AES

Reported in Bulletin #9.

23ME: *Radar Precipitation*

Principal Investigator: D.M. Pollock - AES

No report.

24ME: *Climatological Studies*

Principal Investigator: D.W. Phillips - AES

"IFYGL Weather Data" has been published and distributed for April 1972 through May 1973. The final summary, June 1973, has been completed and is being published. Submission to the Data Bank will follow completion, likely in early April.

25ME: *Lake Ontario Evaporation by Mass Transfer*

Principal Investigator: J.G. Irbe - AES

Completed.

26ME: *Wind and Humidity Ratios*

Principal Investigator: M.S. Webb - AES

Reported in Bulletin #9.

27ME: *Island Precipitation Network*

Principal Investigator: J.A.W. McCulloch - AES

Reported in Bulletin #9.

28BL: *Momentum, Heat, and Moisture Transfer*

Principal Investigators: G.A. McBean, H.C. Martin, R.J. Polavarapu - AES

Reported in Bulletin #9.

29BL: *Space and Time Spectra*

Principal Investigators: F.B. Muller and C.D. Holtz - AES

No report.

30F: *CCGS Porte Dauphine - IFYGL - Operations*

Principal Investigator: G.K. Rodgers - CCIW

Completed.

32EB: *Thermal Bar Study*

Principal Investigator: G.K. Rodgers - CCIW

Completed.

33 included in 32EB.

34WM: *Circulation near Toronto*

Principal Investigator: G.K. Rodgers - CCIW

Completed.

36EB: *Electronic Bathythermograph*

Principal Investigator: G.K. Rodgers - CCIW

Completed.

38TW: *Groundwater Contribution to Lake Ontario*

Principal Investigator: R.C. Ostry - OME

Field work was completed on schedule for this project and the report writing phase is presently continuing with an anticipated completion date of March 31, 1974. Two papers relating to hydrogeology and hydrochemistry were presented at the 16th IAGLR Conference in April 1973. At the present time, one report entitled "Hydrogeology Along the North Shore of Lake Ontario in the Bowmanville-Newcastle Area" is in press. Work is continuing on the investigation of remote sensing techniques to assess their applicability to hydrology and hydrogeologic studies. This aspect of the program is being carried out in co-operation with other government and university agencies.

40WM: *Coastal Chain Study*

Principal Investigator: G.T. Csanady - University of Waterloo

Completed.

42EB: *Heat Storage of Lake Ontario*

Principal Investigator: F.M. Boyce - CCIW

The data has been worked-up and analysis is proceeding towards a report in June 1974.

43EB: *Internal Wave Measurements*

Principal Investigator: F.M. Boyce - CCIW

The data has been worked-up and analysis is proceeding towards a report in August 1974.

44BL: *Analysis of Energy Fluxes*

Principal Investigator: F.C. Elder - CCIW

Reported in Bulletin #9.

45WM: *Lake Current Measurements*

Principal Investigator: E.B. Bennett - CCIW

Reported in Bulletin #9.

46TW: *St. Lawrence-Niagara River Measuring Program*

Principal Investigator: E.A. MacDonald - DOE, Hydrology

Data and report being submitted to the Data Bank in early March 1974.

47TW: *Computer Modelling*

Principal Investigator: L.E. Jones - University of Toronto

No report.

49TW: *Snow Stratigraphy and Distribution*

Principal Investigator: W.P. Adams - Trent University

No report.

54BC: *Groundwater Supply near Kingston*

Principal Investigator: W.A. Gorman - Queen's University

Completed.

55EB: included in 32EB.

62ME: *Evaporation Synthesis*

Principal Investigator: J.A.W. McCulloch - AES

Reported in Bulletin #9.

63EB: *Airborne Ice Reconnaissance*

Principal Investigator: T.B. Kilpatrick - AES

Reported in Bulletin #9.

64ME: *Basin Evapotranspiration*

Principal Investigator: H.L. Ferguson - AES

Reported in Bulletin #9.

65ME: *Special Shoreline Evaporation Pan Network*

Principal Investigator: J.A.W. McCulloch - AES

Reported in Bulletin #9.

66ME: *Atmospheric Water Balance Study*

Principal Investigator: H.L. Ferguson - AES

Reported in Bulletin #9.

67ME: *Surface-Water Temperature Distribution*

Principal Investigator: M.S. Webb - AES

Reported in Bulletin #9.

68F: *CCIW Supporting Resources*

Principal Investigator: J.P. Bruce - CCIW

Continues.

69TW: *Pleistocene Mapping*

Principal Investigator: E.P. Henderson - GSC

This project is a joint Canadian-United States venture. The Ontario half of the data has been collected and processed. The U.S. submission is expected by August, 1974 and final mapping will begin in October 1974.

70WM: *Ground Truth for Remote Sensing*

Principal Investigator: A. Falconer - University of Guelph

Progress in this project is approximately on schedule. A series of thematic maps using topics related to hydrology are in preparation for the Lake Ontario Basin. These maps are produced using an ERTS

photographic base. Work using ERTS bases for different seasons with the appropriate thematic data, is in progress. Evaluation of ERTS high altitude data for hydrologic purposes is producing interesting results in the areas of mapping high chlorophyll concentrations in lakes, in mapping snow and snow melt. Hydrologic characteristics of the landscape can also be rapidly mapped using remote sensing data for evaluation of drainage nets and certain parameters of large watersheds. Remote sensing provides a wealth of detail about land use in the various drainage basins. The incorporation of these data into models of run-off and sediment yield appears to be possible. Patterns of lake movement, sediment dispersion in lakes, and the concentration of different turbidity regimes in a water mass can all be efficiently mapped on a regional scale for the remote sensing data.

Other investigators who would be interested in using the mapping techniques described above, or in integrating their data with remote sensing information now available in this project, should contact me.

71EB: *Canadian Radiation Network*

Principal Investigator: J.A.W. McCulloch - AES

Completed.

72EB: *Floating Ice Research*

Principal Investigator: R.O. Ramseier - DOE, Ice

The Floating Ice Section is currently in the process of completing its third winter of ice studies on the St. Lawrence River. The emphasis has been on using over 50 ground sampling sites as both our primary initial data source and as a ground truth check on the development of a variety of promising remote sensing techniques including a PRT 5 radiometer, false colour infrared imagery, standard aerial photography and lately an airborne impulse ice thickness radar unit. The original mission objective was extended in 1972 to include ice sampling between the Thousand Islands Bridge and Montreal. Large scale mechanical testing of St. Lawrence River ice was completed in 1972. Water temperature measurements at the Lake Ontario entrance have been made on a continuous basis covering the period preceding ice formation right through to post-break up for 1972-73 and 1973-74.

Unusually mild weather last winter delayed our plans to obtain current measurements under the ice cover until this year when once again warm weather made all ice sampling very difficult.

The following reports have been written covering our work over the past two winters:

Navigation Season Extension Studies

Gulf of St. Lawrence to Great Lakes
Ministry of Transport, Winter 1971-72, 1972-73.

Studies on the Extension of Winter Navigation in the St. Lawrence River. Proceedings, IAHR Ice Symposium, Budapest, Hungary, January 1974.

F.M. Radar Ice Thickness Measurements
Department of Communications
Communications Research Centre, Technical Report (in preparation)

A New Approach to Field and Laboratory Tests of Tensile, Compressive and Flexural Strength of Polycrystalline, Fresh Water Ice. Proceedings, IAHR Ice Symposium, Leningrad U.S.S.R., 1972.

73EB: *Terrestrial Heat Flow*

<u>Principal Investigator</u>: A. Judge - EM&R

As part of a study of the terrestrial heat flow throughout the Great Lakes Region, ten measurements of the temperature gradient, to depths of three metres, were taken in the bottom sediments of the deep water areas of Lake Ontario. Thermographs were installed so as to measure bottom-water temperatures in each of the three deeper areas and were successfully recovered after one year's operation. Three two-metre cores of bottom sediment were also recovered from thermal conductivity measurements. Preliminary heat flow values from these sites indicate values not substantially different from the surrounding on-shore determinations.

Judge, A.S. Geothermal Measurements in a sedimentary basin
Ph.D Thesis University of Western Ontario. 1972.

Judge, A.S.
& A.E. Beck Analysis of Heat Flow Data - Several Boreholes in a Sedimentary Basin
Canada J. Earth Science <u>10</u> p. 1494-1507. 1973.

Judge, A.S. Heat flow in the Grenville
oral presentation "Evolution of the Grenville Province"
Ottawa February 1974.

74TW: *Water Level Network*

<u>Principal Investigator</u>: G.C. Dohler -MSD

All the water level data along the Canadian coastline has been collected, processed and stored in CCIW Data Bank in Burlington. The

responsibility for analyzing the data has been taken over by Mr. N.G. Freeman, Marine Sciences Directorate, Central Region. Analysis will start by August 1974.

75BL: *Wind and Temperature Fluctuations*

Principal Investigators: S.D. Smith and E.G. Banke - Bedford Inst.

Reported in Bulletin #9.

76WM: *Surface Wave Studies*

Principal Investigator: G.L. Holland - MSD

Reported in Bulletin #9.

78TW: *Basin Water Balance*

Principal Investigator: M. Sanderson - University of Windsor

Analysis of data suspended until 1975.

79F: *Bathymetric Surveys - Lake Ontario*

Principal Investigator: T.D.W. McCulloch - CCIW

Completed.

80EB: *IFYGL Radiation Balance Program*

Principal Investigator: J.A. Davies - McMaster University

The data has been worked up and final reports are being currently reviewed.

81BC: *Materials Balance - Lake Ontario*

Principal Investigator: S. Salbach - OME

Reported in Bulletin #9.

82BC: *Lake Ontario Zooplankton Migration*

Principal Investigator: J.C. Roff - University of Guelph

Reported in Bulletin #9.

83BC: *Co-operative Studies of Fish Stocks*

Principal Investigator: W.J. Christie - OMNR

Reported in Bulletin #9.

84BC: *Cladophora Growth*

Principal Investigator: G.E. Owen - OME

Reported in Bulletin #9.

85BC: *Nutrient Cycles - Lake Ontario*

Principal Investigator: P. Stadelmann - CCIW

Reported in Bulletin #9.

86BC: *Lake Ontario Surface Chlorophyll Survey*

Principal Investigator: H.F. Nicholson - CCIW

Reported in Bulletin #9.

87EB: included in Project 42EB.

89WM: *Turbulent Diffusion Studies*

Principal Investigator: C.R. Murthy - CCIW

Extensive report in this Bulletin.

90WM: included in Project 89WM.

94: *Data Retransmission by Satellite*

Principal Investigator: H. MacPhail - CCIW

Complete.

95WM: *Hydrodynamical Modelling*

Principal Investigator: J. Simons - CCIW

Reported in Bulletin #9.

96WM: included in Project 45WM.

97BL: *Meteorological Buoy Measurements*

Principal Investigator: F.C. Elder - CCIW

Reported in Bulletin #9.

98BC: *Lake Ontario Cross-section Study*

Principal Investigator: G. Carpenter and M. Munawar - CCIW

Reported in Bulletin #9.

101BC: *Lake Ontario Primary Production Study*

Principal Investigator: P. Stadelmann and M. Munawar - CCIW

Reported in Bulletin #9.

102BC: *Lake Ontario Diel Pigment Variation*

Principal Investigators: W. Glooschenko and M. Munawar - CCIW

Chlorophyll a samples taken every two hours have been analyzed for OOPS Station 11 (1, 5, 10M) and 19 (1, 10 20M). Preliminary results indicate that no regular pattern occurred in chlorophyll concentrations over the 48 hour periods occupied upon each station. Concentrations differed significantly at the two hour intervals, especially during thermal stratification periods. Mechanisms that explain this include light levels too low to cause bleaching of pigments, horizontal patchiness, and advection of water masses past the station. Currently, physical parameters, such as currents and wind induced turbulence are being examined as to their effect upon chlorophyll concentrations. A paper with these results is being prepared for the 1974 Great Lakes Conference to be held in August.

103BC: *Pesticide Concentration in Bird's Eggs*

Principal Investigator: M. Gilbertson - CWS

Reported in Bulletin #9.

104BC: *Rain Quality Monitoring*

Principal Investigator: P. Stadelmann - CCIW

Reported in Bulletin #9.

107BL: *Air Pollution Sinks*

Principal Investigator: D.M. Whelpdale - AES

Reported in Bulletin #9.

108BL: *Lake Level Transfer*

Principal Investigator: G.C. Dohler - MSD

Water level data has been collected at Point Petre and they are available on punched cards. The sampling time is 15 minutes for both recorders.

Storm surge simulation has been studied in the area of Point Petre and results will be presented at the next IAGLR Conference in McMaster University in August.

Statistical study of the past water level data has been done and it was found out that water level transfer was possible during "calm" days on the lake.

Further analysis will be done by Mr. N.G. Freeman, Marine Sciences Directorate, Central Region, using the meteorological data collected on the shore of Lake Ontario during IFYGL.

109WM: *Upwelling Study*

Principal Investigator: G.K. Rodgers - CCIW

Reported in Bulletin #9.

110WM: *Hydro Intake Study*

Principal Investigator: A. Arajs - Ontario Hydro

Reported in Bulletin #9.

111WM: *Lakeview Dispersion Study*

Principal Investigator: M.D. Palmer - OME

Reported in Bulletin #9.

112BC: *Threespine Stickleback*

Principal Investigator: E.T. Garside - Dalhousie University

Reported in Bulletin #9.

114WM: included in Project 89WM.

115WM: *Wave Climatology*

Principal Investigator: H.K. Cho - CCIW

Source of data

During IFYGL 10,040 visual estimates were taken from three Canadian and two U.S. research ships.

Additional wave data reported from voluntary commercial ships and data derived from wave gauge records (IFYGL Project 76WM surface wave study) were used for wave comparison.

Frequency distribution

The cumulative frequency on Logarithmic scale of wave heights observed on Lake Ontario is shown in Figure 1, along with those determined from the ten-year data.

The maximum wave heights of 4.0m or more were observed during the winter season.

The percentage of wave heights less than 0.5 meter was 23% for the winter season and 56% for the summer season respectively.

A scatter plot of wave heights and wave periods have shown an average wave steepness of 0.03 - 0.04.

Wave height comparison

In order to assess the standard of accuracy of the observations taken from the Research ships and the Voluntary Observing ships, a comparison was made with wave gauge records.

In Figure 2, the bias obtained from Research ships has shown higher correlation than that of commercial ships. It is very likely that the higher waves were generally overestimated.

N.B.
The final report will be made published in August 1974.

116TW: *Airborne Gamma Ray Snow Survey*

Principal Investigator: H.S. Loijens - IWD, Glaciology

Reported in Bulletin #9.

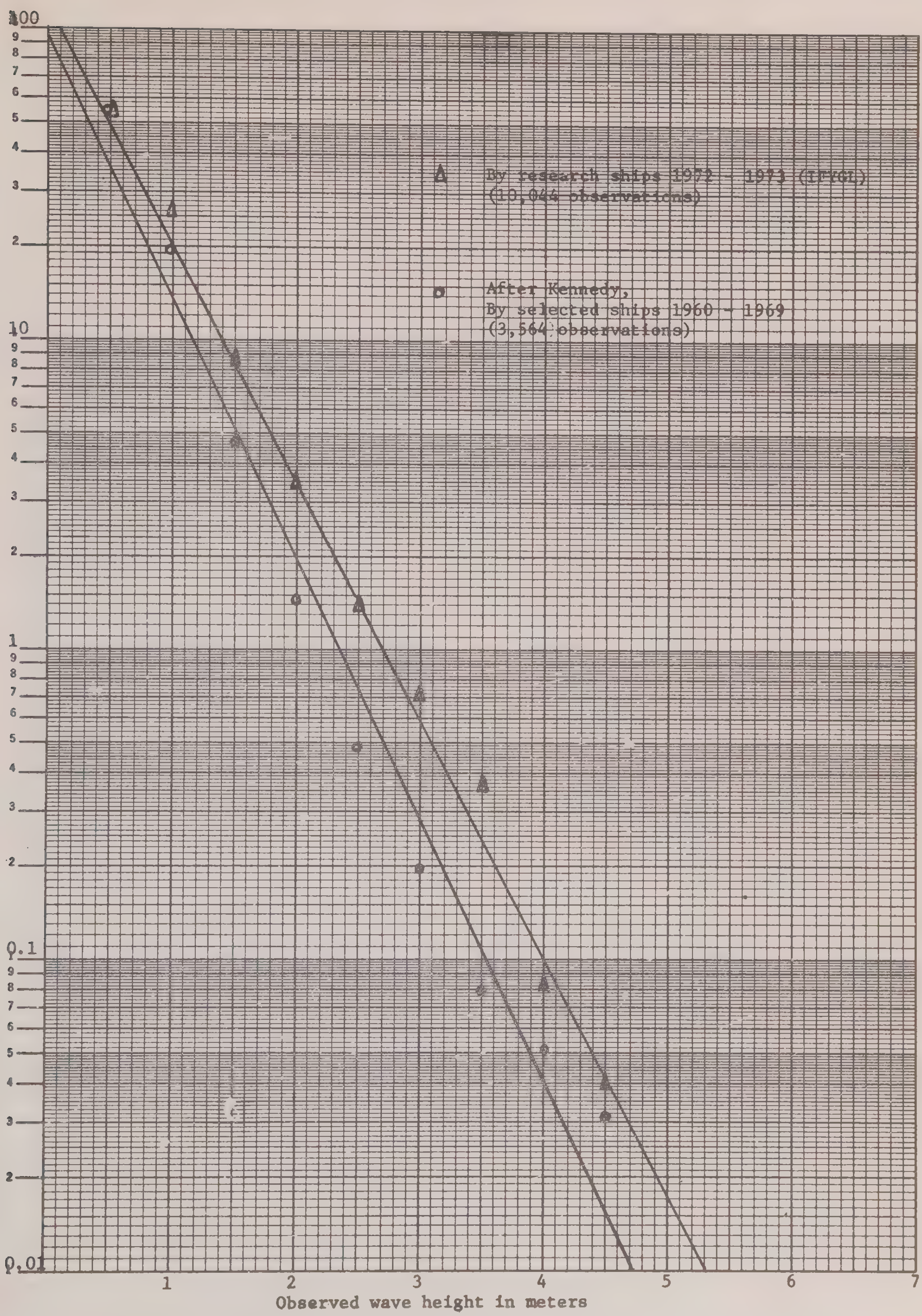

Figure 1. Cumulative frequency on logarithmic scale of wave heights observed on Lake Ontario.

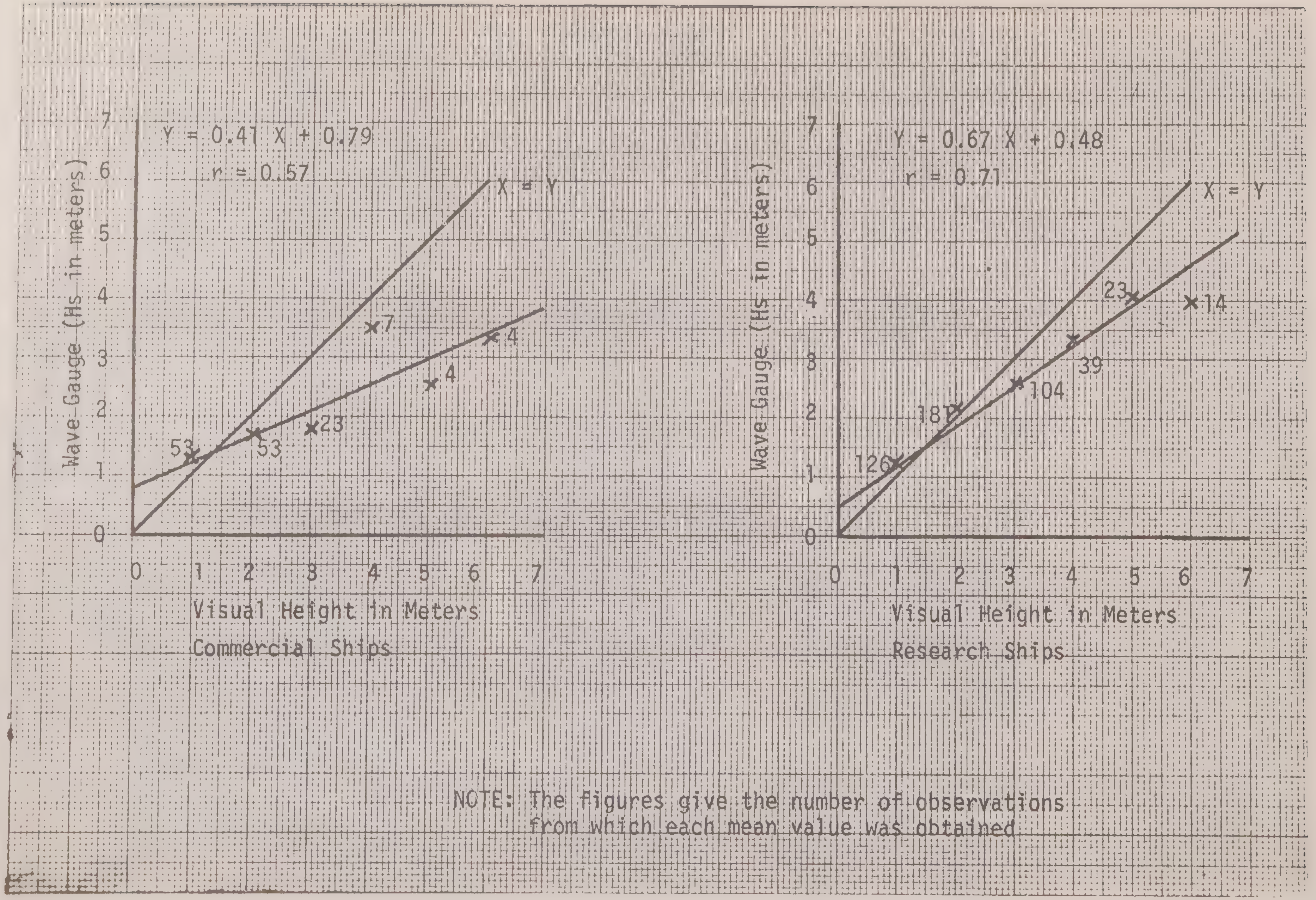

Figure 2. Wave height comparison.

117ME: *APT Photographs*

Principal Investigator: J.A.W. McCulloch - AES

Because it appeared that these would be of assistance to various investigators, the AES Satellite Data Laboratory has agreed to provide a copy of each APT frame received at Toronto during IFYGL which contained the Lake Ontario Basin. At the moment, the largest problem seems to be in selecting the best method to enter these into the IFYGL archive.

118: *General Publications*

Principal Investigators: J. Byron - CCIW

This project has been created to serve as a means to archive publications which cannot be attributed directly to a specific project. Many of these publications include early feasibility studies and policy statements.

LARGE SCALE DIFFUSION STUDIES

(IFYGL PROJECT 89WM)

Project Team: C.R. Murthy, G. Kullenberg, H. Westerberg, K.C. Miners.

Introduction

The circulation and water movements in natural bodies of water such as the Oceans and the Great Lakes are generally very complex turbulent motions. Superimposed on the mean flow circulation patterns are eddy-like motions of varying intensity and scales. These eddy-like motions exist in both horizontal and vertical directions; the scale of horizontal eddies, however, are much larger than the vertical eddies because the lakes (or the Oceans) are many times wider than they are deep. A direct consequence of this is the large scale water movements and the associated transport and dispersion of chemical and biological species from one area of the lake to another. The practice of discharging municipal and industrial wastes including waste heat from thermo-nuclear power plants (and radioactive materials into the oceans) provided impetus for extensive theoretical and experimental studies of turbulent diffusion processes in natural bodies of water. However, tubulent diffusion processes are undoubtedly complex and theoretical predictions of dispersion of these wastes are far from satisfactory. Thus, an understanding of the various manifestations of turbulent diffusion processes is largely dependent on the empirical approach of conducting field diffusion experiments. This report is a documentation of the experimental observations of large-scale diffusion studies carried out during MELON[1] (1969) and IFYGL[2] (1972) in Lake Ontario.

Experimental Methods

The experimental technique consisted of generating a "dye patch" at selected depth by instantaneous release of a slug of rhodamine B dye solution and following the subsequent diffusion of the dye patch as the lake currents and their eddies cause it to spread and dilute. The density of rhodamine B dye solution (40 per cent acetic acid) was adjusted to the <u>in situ</u> density by adding methanol and surface water. Water samples taken at the selected depth of dye injection were used to determine the <u>in situ</u> density. No attempt was made to adjust the temperature of the dye solution to the <u>in situ</u> temperature, and usually the initial mixing during the injection was sufficient to compensate for the temperature difference. The method of dye release and the fluorometric sampling of the dye patch varied somewhat for the surface layer (epilimnion) and deep water (thermocline and hypolimnion) experiments and it is of interest to describe them in some detail separately.

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[1] Massive effort on Lake Ontario - an IFYGL feasibility study.

[2] International Field Year for the Great Lakes.

Epilimnion Experiments

During 1969 series of experiments, a pontoon platform 8m x 3m anchored 15 km off Port Credit (Fig. 1) was used to release the dye. A 750 litres (200 gal) storage tank permanently mounted on the raft was used to store the dye solution. A high volume centrifugal pump powered by a portable gasoline generator was used to release the dye. The dye solution from the storage tank was pumped through a vertically mounted discharge pipe 4 cm. dia. extending 5m below the surface with a diffuser section consisting of 1.25 cm. holes uniformly distributed. The diffuser pipe was supported by four cables connected to the bottom of the deck. The release time for 500-750 litres of dye solution was about 2-3 min and thus the dye patch could be treated as instantaneous.

During 1972 series of experiments, a specially built *in situ* dye release system was used. The system consists of fibre glass cylinder and an aluminium end-plate assembly with a release mechanism. The *in situ* preparation of dye release system consists of positioning the end-plate assembly in the cylinder and sealing it with inflated bicycle inner tubes. The entire assembly is supported by cables from a winch during preparation. The cylinder is lowered to the water and filled with dye solution via hydraulic connectors at the top. When full, the cylinder is lowered to the desired depth. A messenger weight dropped down the cable triggers the air valve to the seals. When the seals deflate sufficiently the cylinder drops down and the dye solution is released almost instantaneously. The dye patch thus generated is allowed to drift away from the area of release before recovering the dye release system.

Generally the dye release took place in the early hours of the day which constitutes the beginning of the experiment. The early stages of diffusion are difficult to sample since the dye patch has small areal extent and high concentrations beyond the measurability range of the fluorometers. Moreover, any significant disturbance of the patch by the sampling vessel could alter the dispersion characteristics considerably. The dye patch was sampled using launch and/or shipborne fluorometers by a carefully chosen network of crossings across the patch. Launch based operation was used for sampling when the diffusing patch was small (say hundreds of metres). When the diffusing patch had grown to the size of a few kilometres, a larger vessel (CSS LIMNOS) was used for sampling the dye patch. In order to obtain as rapid (quasi-synoptic) and accurate measurement of the diffusing patch as possible, the sampling procedure was discussed with the crew of the sampling vessels. Their experience, particularly in the areas of navigation was no doubt very valuable. Besides, precision navigation of the sampling boats, accurate book keeping of all sampling courses, speeds and times are necessary for proper synthesis of the data. This, to a large extent, was provided by the crews of the sampling vessels involved.

For the launch-based sampling, the positions of the launches were fixed relative to the anchored mother ship. The positions were marked at the beginning of the crossing and at the end when the fluorometer reading had dropped to zero or a very low value compared to the peak in that crossing. When the ship was used for sampling, direct fixing of position on charts by using the log reading and the compass course was used.

Eight metre length booms were mounted on the portside of the vessels used for sampling the dye patch. The booms were constructed of hollow aluminium extrusion of aerofoil shape to ensure low drag. They could be lowered by cable arrangement so that samples could be drawn in at depths of up to 6m and swung up out of the water to lie along the side of the launches when not in use. Continuous samples were drawn at the leading edge of the boom and pumped through Turner Model 111 continuous flow-through fluorometers on the deck of the sampling vessels. The output signals from the fluorometers were stored on strip chart recorders. A flow rate of approximately 70 cm^3/sec. was maintained to minimize the lag time in the tubing and to obtain good response characteristics from the sampling system. (typical response time of the system was 10 sec.). The on-deck arrangement of the instruments is similar to that described by Murthy (1969). With a boat speed of 2-3 m/sec., a very good resolution on the spatial scale of the strip chart recorder was achieved. The fluorometers were calibrated in the laboratory before the start of the experiments and the sensitivity range in lake water was found to be 10^{-10} - 10^{-6} g/cc.

Thermocline and Hypolimnion Experiments

The density adjusted rhodamine B dye solution was stored in a 100 litres container on board which was interconnected by a pressure hose to a 2m long vertical diffuser closed at the lower end. The injection was accomplished by applying pneumatic pressure using oxygen or nitrogen pressure cylinders, to a second container filled with water and connected to the dye container. The injection generally lasts 2-3 minutes during which time the ship was kept in its position relative to a parachute drogue released earlier at the desired depth. Assuming that the position of the dye relative to the drogue is approximately constant or changing slowly with time, the position of the ship was continuously plotted relative to the drogue, and once the position of the dye spot had been established the tracing was directed by means of the plot. The initial period of the experiment is critical when the dye spot is very small. The tracing must start immediately after the release, and in order to accomplish this the fluorometer had to be lowered to the selected depth before dye injection. In most cases the dye patch and the drogue slowly separated but this had no influence on the tracing until the separation was so large that the position could not be accurately determined. Then a second parachute drogue was usually released. The navigation was done relative to the drogue. The drogue position relative to the ship was determined by taking radar fixes to the drogue. In some cases the drogue could not be detected on the radar screen;then optical positioning, relative to the drogue, was used. Decca fixes establishing the absolute position of the ship were taken on a regular basis during sampling. The cruising of the ship was directed continuously plotting the position relative to the drogue, marking the positions of dye detection in the plot. The sampling was done by towing an in situ fluorometer, continuously recording the dye concentration as well as the temperature, the latter by means of a thermistor mounted on the fluorometer. All the control units were kept on board the ship and the instrument was suspended from a wire with a separate electrical cable. The signals were continuously recorded on a strip chart recorder. The path of the ship was directed by means of the navigation plot so as to cover the area in a systematic manner. The towing of the fluorometer limited the cruising speed to 1-3 knots. This was not a

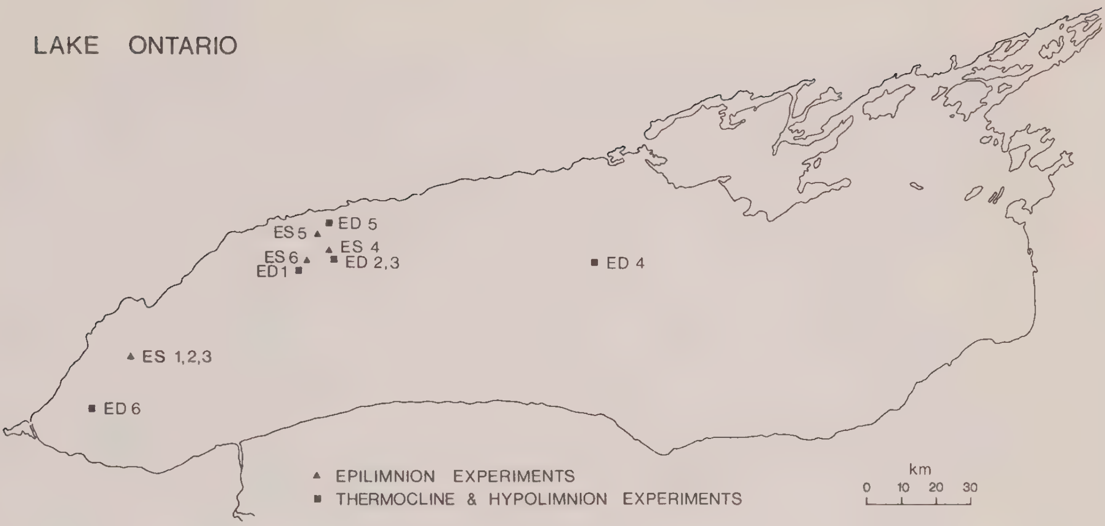

Figure 1. Locations of dye diffusion experiments.

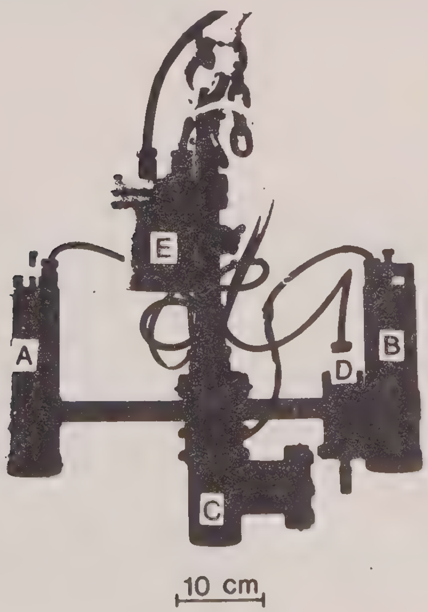

Figure 2. The fluorometer. A-B, photomultiplier tubes; C, light source; D, thermistor; E, depth sensing unit.

serious problem since the horizontal scale covered by experiments was usually less than 1-3 km and the corresponding time required for a complete coverage of the dye patch varied between 1-4 hours. After an initial period, the dye was generally distributed in one or more layers of nearly constant thickness. Therefore, the instrument was always operated in a cyclic mode by winding it through a given depth interval. The downward tracks have mainly been used for analysis.

The fluorometer used in these experiments was of the <u>in situ</u> type developed by Kullenberg (1969). It is of some interest to describe its operation briefly here since operational <u>in situ</u> fluorometers are not yet commercially available. The fluorometer (Fig. 2) consists of two photomultiplier tubes A and B with the photocathodes facing downwards, a lamp house C with a Phillips HKP 125W mercury lamp, a thermistor probe D, and a depth sensing unit E. The green mercury light, separated by glass filters, irradiates horizontally one of the photomultipliers (B). The other tube (A) is only affected by the ambient light which also affects tube B. The influence of the ambient light is approximately eliminated by connecting the tubes against each other. The degree depends essentially upon how well matched the photomultipliers are. The thermistor probe forms part of a Wheatstone bridge, and by adjusting the resistances, different temperature ranges can be covered. This makes it possible to resolve the small scale features, obtaining the temperature structure and the dye distribution simultaneously. The instrument can resolve spatial scales of order 1 cm. A detailed description of the instrument and the experimental technique have been reported earlier by Kullenberg (1969).

The fluorometer was calibrated in the laboratory before the start of the experiments and the sensitivity range in lake water was found to be 10^{-11} - 10^{-6} g/cc.

Data Summary

The general details of the experiments are summarized in Tables 1 and 2. A total of 12 experiments distributed in the epilimnion, thermocline and hypolimnion were conducted under a wide variety of environmental conditions Fig. 1 shows the geographic distribution of the experiments. The epilimnion experiments covered time scales from 3 to 60 hours and the corresponding spatial scales ranged from 100m to 15km in the horizontal and up to 6m in the vertical. The thermocline and hypolimnion experiments covered time scales from 5 to 80 hours and the corresponding spatial scales ranged from 100m to 3km in the horizontal and 10cm - 1m in the vertical. All the experiments during 1972 series were carried out in the vicinity of IFYGL meteorological and current meter moorings to take advantage of the general environmental data to interpret diffusion data and results. The experimental data after preliminary analysis is presented under the following headings:

Horizontal Diffusion

Horizontal distributions of dye concentration were prepared for each experiment from a good coverage of the dye patch during a reasonable sampling time interval and thus they could be treated as quasi-synoptic. The diffusion

*Table 1. General Details of Thermocline and Hypolimnion Experiments**

EXPERIMENT NUMBER	DATE	DURATION (hrs.)	DEPTH IN METRES OF:			DRIFT		AMOUNT OF DYE RELEASED (kg)
			DYE	THERMO-CLINE	BOTTOM	DIRECTION (TOWARD)	SPEED (cm/sec)	
ED1	15–08–72 to 19–08–72	79	18–26	11	90 100	250°	12.6	8
ED2	29–08–72 to 30–08–72	30	35–45	7	85	090°	4.4	4
ED3	31–08–72 to 02–09–72	40	33–43	11	85	260°	7.8	5
ED4	06–09–72 to 08–09–72	60	25–35	14	110 120	140° 270°	2.8 1.5	4
ED5	27–09–72 to 28–09–72	24	20–30	18	40	225° 180°	2.7 4.5	6
ED6	17–10–72 to 20–10–72	72	25–50	14	85 60	230° 360°	2.1 2.9	12

*For locations, see figure 1.

*Table 2. General Details of Epilimnion Experiments**

EXPERIMENT NUMBER	DATE	DURATION (hrs.)	DEPTH IN METRES OF:			AMOUNT OF DYE RELEASED (kg)
			DYE	THERMOCLINE	BOTTOM	
ES1	07–05–69	3.5	3	HOMOGENEOUS	80	155
ES2	17–06–69 to 18–06–69	30.7	3	10	80	250
ES3	26–08–69 to 28–08–69	58.1	3	15	80	250
ES4	30–05–72	3.8	3	3	46	125
ES5	05–06–72	6	3	<1	22	185
ES6	27–06–72 to 29–06–72	53	1	3	73	125

* For locations, see figure 1.

time is taken from dye release to middle of the interval chosen for constructing the horizontal distributions. Preparation of these plots was straight forward for surface layer (epilimnion) experiments where continuous sampling was carried out. In deep water experiments (thermocline and hypolimnion) where the sampling was discrete the distributions were constructed in the following manner. From the observed vertical concentration profiles, the mean concentration was determined and plotted on a two-dimensional horizontal plot. Quite often sloping layers of dye were observed presumably due to internal wave activity. In this analysis a sloping layer was represented as if it were horizontal.

The horizontal dye distributions are relative to the drogue in a system moving with the mean current. It is usually not necessary to correct for the translation during the sampling interval since the analysis of the data is carried out in a moving frame of reference (relative diffusion).

A mass balance calculation using the areas of the isopleths and the mean thickness of the dyed layer checked reasonably well in all experiments, (i.e.) usually between 50 to 100 per cent.

Quasi-synoptic horizontal distributions of dye concentrations prepared for each experiment are summarized in CCIW Paper No. 14 (1974).

The generally elongated shape of the horizontal distributions suggest that the vertical shear-diffusion mechanism is an important factor in horizontal mixing. The "shear effect", (i.e.) in the present context is the dispersion of a vertical column caused by the combined effect of the vertical current shear and the vertical mixing, has been shown to have significant effect on the horizontal dispersion (Bowles et al., 1958; Bowden, 1965; Carter and Okubo 1965 and others).

Vertical Diffusion

The experimental data presented in this section refers only to deep water experiments (thermocline and hypolimnion);the data from surface layer experiments were not detailed enough to be included in this report. The vertical diffusion data collected during these experiments are too detailed to be presented here in total. However, examples are included to illustrate the characteristics of vertical mixing.

In conditions of relatively strong stratification and vertical shear, the dye is usually detected in very well defined layers with sharp boundaries and nearly homogeneous vertical concentration distribution. The layers are very persistent and the thickness is virtually constant over significant periods of time during which the concentration in the layer decreases slowly. The vertical mixing appears to be ultimately coupled with the formation and destruction of these layered structures. The layers are apparently related to the density and current structure. By means of the simultaneous temperature record, various layers, situated in different parts of the temperature field can be identified with increasing diffusion time. Well defined layers are identified throughout each experiment and Fig. 3 is a typical illustration. An examination of the different layer types encountered in the

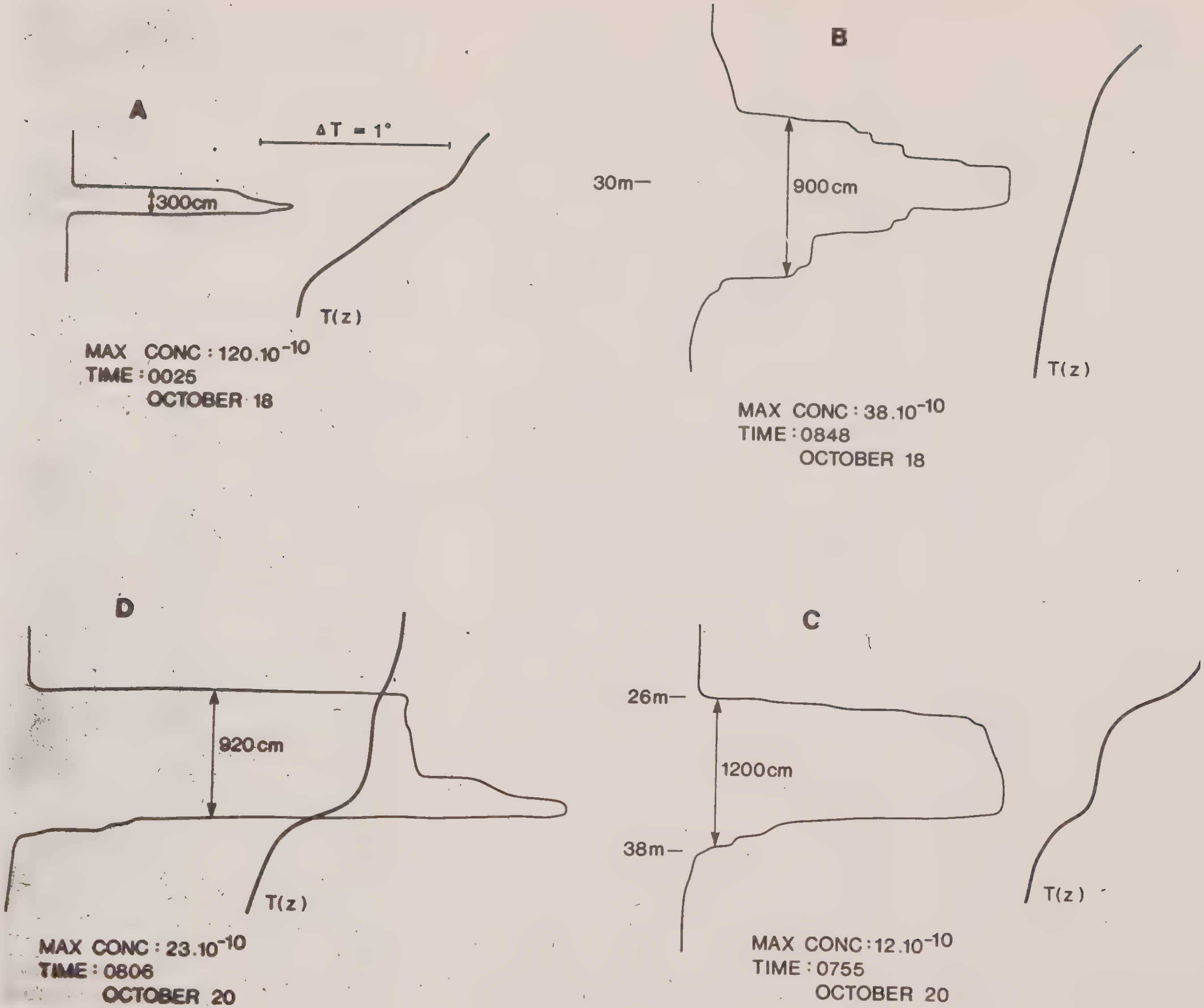

Figure 3. Typical vertical concentration profiles, Experiment ED6, Oct. 18-20, 1972.

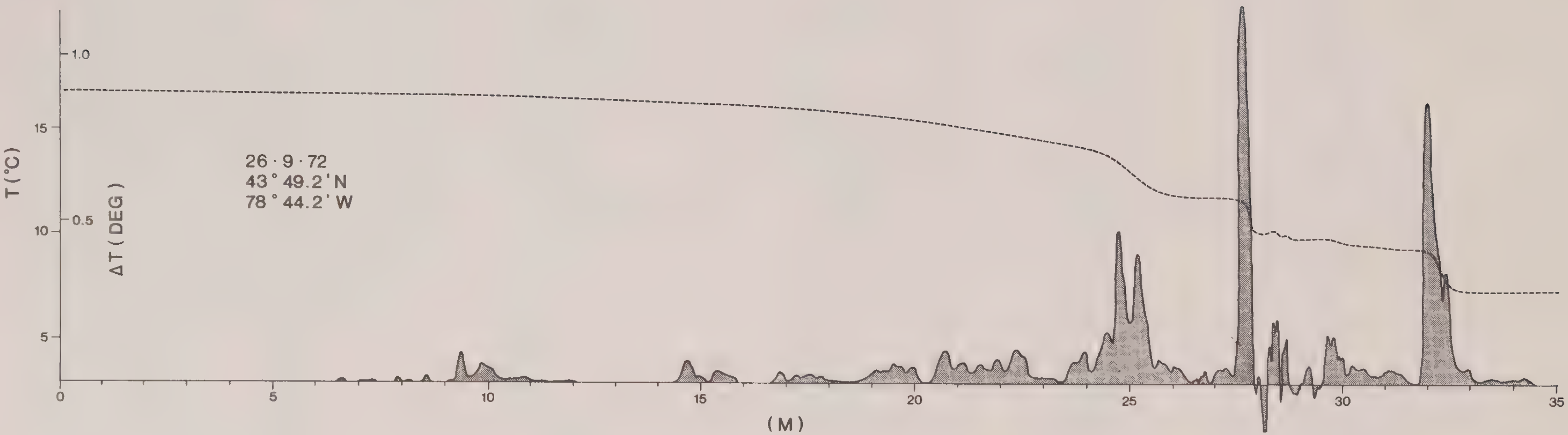

Figure 4. Typical trace of small scale temperature preceding Experiment ED5.

experiments shows that the sharp, pulse-shaped layers when seen in a vertical distribution of dye concentration are connected to relatively strong density gradient layers. The current shear is also relatively marked in these regions. The shear tends to stretch the dye layer thereby decreasing its thickness, whereas the vertical mixing tends to increase the thickness. An approximate balance between these two effects can be postulated leading to the formation of sharp layers with a virtually constant thickness.

In order to relate the observed vertical dye distributions to the temperature structure, detailed measurements of small scale temperature structure in the dyed layer were made on several occasions. Fig. 4 shows an example of one such recording. The main feature, similar to all the observations, is the large variations in vertical temperature gradient throughout the thermocline.

The temperature changes are concentrated in layers a meter thick or less, where the gradient is at least an order of magnitude larger than the mean gradient. Between these gradient layers are almost homogeneous layers, the thickness of which varies from several meters down to the resolution of the instrument.

The horizontal extent of these structures can be estimated from a time series of recordings if the advection of the layers is known. Figure 5 shows an example of this. The current was approximately 10 cm/s, and the displacement between the recordings is about 50 m. The magnitude and detailed structure of the gradient layers varies, but many features are recognizable throughout several recordings, indicating a horizontal scale more than 100 times the vertical.

The violent fluctuations and temperature inversions around 28 m depth in Figure 4 can be interpreted as turbulent eddies and shows no coherence over a 10 m horizontal distance.

The detailed vertical distribution of dye is related to this fine structure in temperature. The vertical current shear seems to be concentrated to the layers of strong density gradient, and this causes a strong dispersion of the dye in these layers. In the intervening layers of small density gradient the dye is well mixed in the vertical.

A simplified picture of what is seen shows a relatively small patch of concentrated dye in an isothermal layer, bounded above and below by layers of strong temperature gradient. Vertical diffusion of dye into the gradient layers and the shear give rise to a thin sheet of dye extending in the direction of the shear. An example of this situation is given by the two vertical profiles of concentration and temperature in Figure 6.

In most cases the dye is distributed in several of the homogeneous layers, which move slowly relative to each other. Figure 7 shows a section through a dye patch where the vertical coordinate is temperature, the scale being chosen to correspond to a linear depth scale for the smoothed mean temperature profile. This gives some errors in the local thickness of the dye, but shows how the shear distorts the dye cloud relative to the temperature field. The part of the cloud between 5.3 and 6.3^{o}C contains several alternating strong and weak density gradients.

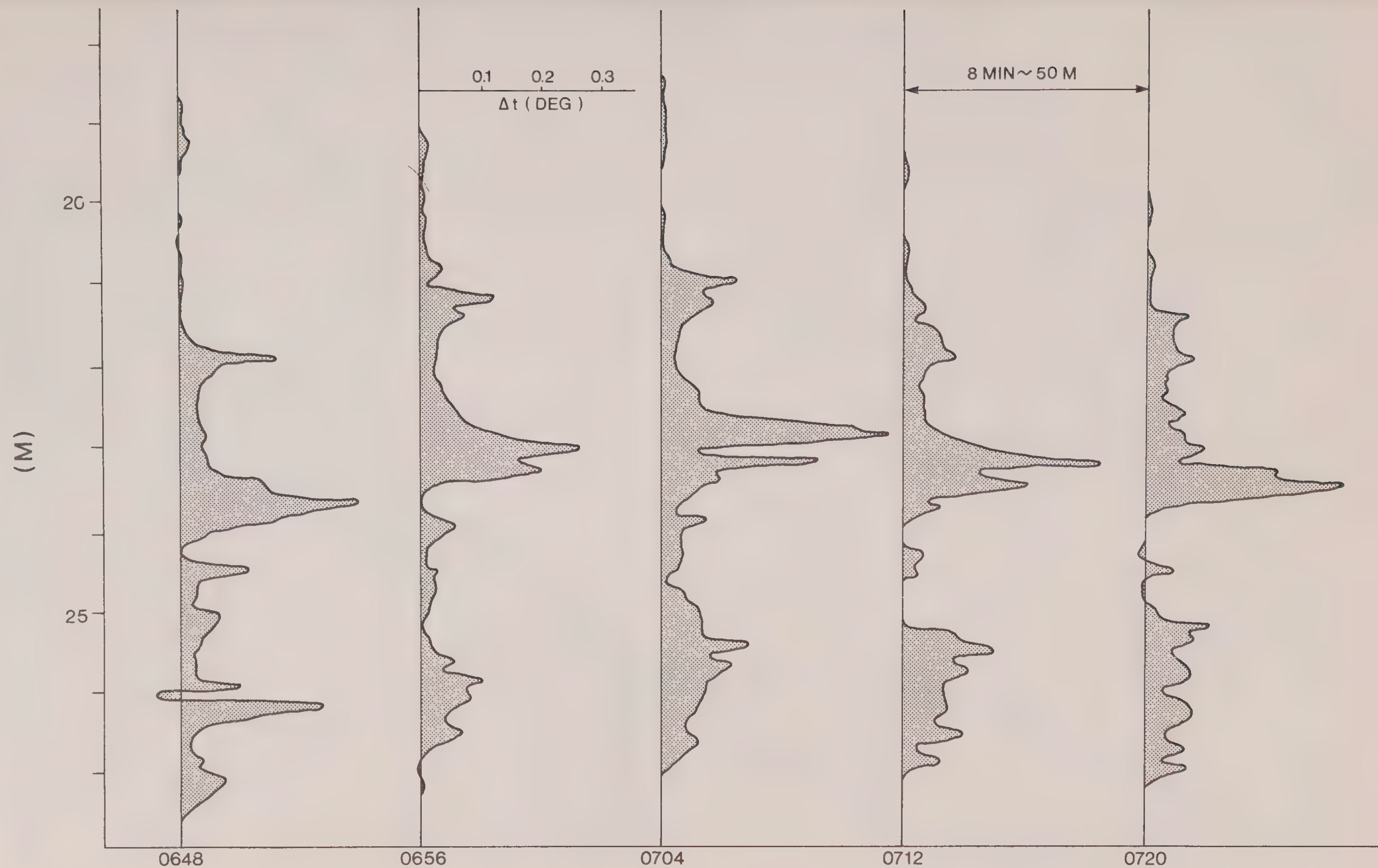

Figure 5. Horizontal scale estimation from time series small scale temperature data from Sept. 26, 1972.

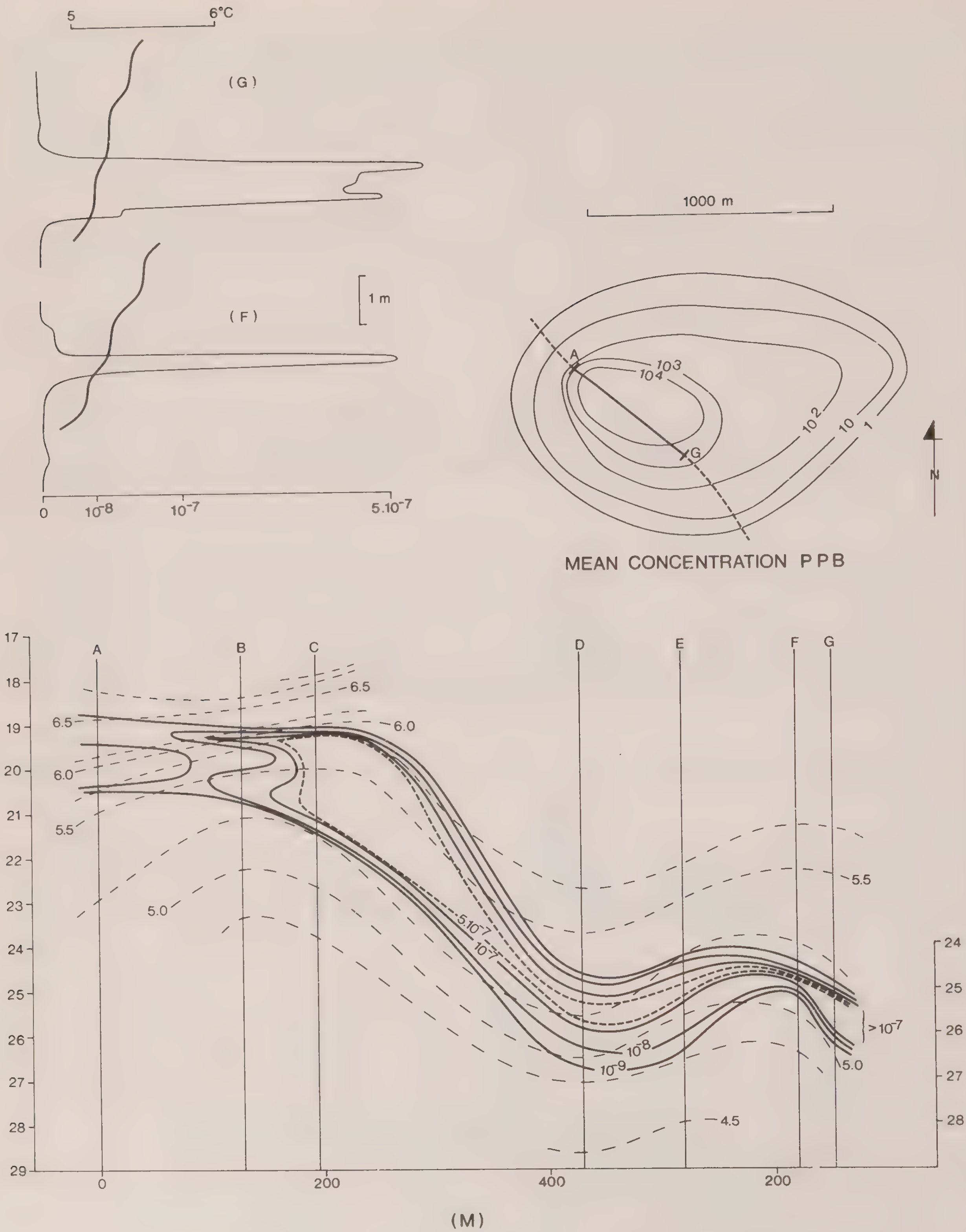

Figure 6. Synoptic dye distribution, Experiment ED1, Aug. 17, 1972, 36 hr. after dye release.

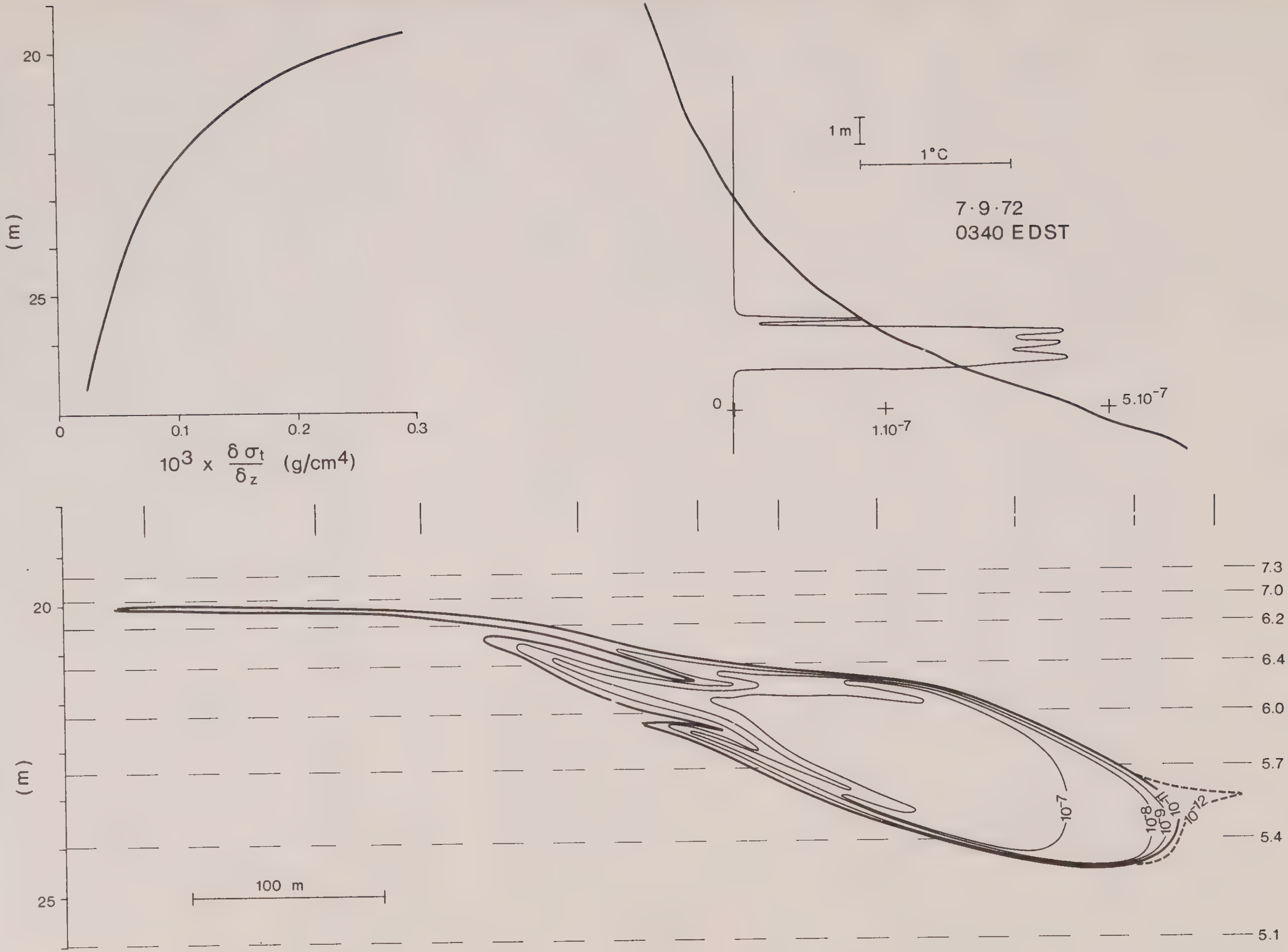

Figure 7. Synoptic dye distribution, Experiment ED4, Sept. 7, 1972, 21 hr. after release.

A section versus depth is given in Figure 6. The same kind of horizontal distortion by a weak shear is seen, the picture being somewhat complicated by an internal wave.

Environmental Data

Whenever possible during the diffusion experiments, current profile measurements in the depth interval of interest were made from an anchored launch in the vicinity of the dye patch. Marine Advisers 5-bladed, deck readout Q-15 and Ekman current meters were used. On some occasions a group of 4-6 drogues set at the depth range of dye were released and tracked for periods of time. Thermal structure was measured at frequent intervals by taking temperature profiles with the ships electronic bathy-thermograph. In addition to these observations, the small scale temperature structure in the thermocline was measured on several occasions using an array of three fast response thermistors mounted approximately 6 cm apart in the vertical. The array was lowered on a cable using a constant speed electric winch. The temperature and temperature differences were recorded on a strip-chart recorder. Depth scale information needed to determine the temperature gradient was obtained by measuring the length of cable paid-out. Meteorological data collected during the experiments were extracted from the ship's weather observations.

In addition to the observations carried out during the diffusion experiments, continuous, measurements of current structure, temperature and meteorological data are available from IFYGL current, meteorological and fixed temperature profiler moorings in the vicinity of the diffusion experiments. Fortunately the data return from these moorings during the period of our experiments was particularly good; thereby enhancing the confidence of our interpretation of diffusion data and results. All the relevant environmental data collected during diffusion experiments are summarized in CCIW Paper No. 14 (1974).

Diffusion Characteristics

The experimental data suggests that the horizontal scales of motions in the lakes (and Oceans) are much greater than the vertical scales and therefore, in many cases their effect on mixing may be considered separately. This idea has been explored by a number of investigators with considerable success. In this approach it is assumed that the introduced substance is subject to horizontal mixing within a sufficiently thin homogeneous layer so that all vertical variations in both concentration and velocity may be neglected. The importance of vertical diffusion, however, cannot be neglected even though the diffusing contaminant is, for practical purposes, confined to a very thin layer. The combined action of vertical shear in the horizontal mean current and vertical diffusion may produce considerable effective horizontal diffusion.

The starting point in the analysis of field diffusion data is the calculation of the variances from the measured spatial concentration distributions of the dye patch. Often the measured concentration distributions

are converted to equivalent radial symmetric distributions from which variances are calculated. It is implicit in such an analysis that the diffusion of the dye patch is governed by two-dimensional homogeneous turbulence. The elongated appearance of the dye patch and the asymmetry in the observed concentration distributions does not support his hypothesis. On the other hand, anisotropic turbulence (meaning turbulent eddies are more intense in the direction of the mean flow than across it) combined with "shear diffusion" due to vertical shear in the horizontal mean current gives rise to enhanced mixing in the longitudinal direction. With these observed features in mind, we compute the variances by direct integration of the observed concentration distributions. Choosing a convenient rectangular co-ordinate system through the centre of the distribution with x-axis in the direction of the mean current, the appropriate variances corresponding to two-dimensional concentration distribution C(x,y,t) are defined by:

Longitudinal,

$$S_x^2\,(t) = \frac{1}{Q}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} x^2\,C(x,y,t)\,dxdy$$

Transverse,

$$S_y^2\,(t) = \frac{1}{Q}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} y^2\,C(x,y,t)\,dxdy$$

and for two-dimensional elongated patch,

$$S_{xy}^2 = S_x^2\,(t) + S_y^2\,(t)$$

where

$$Q = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} C(x,y,t)\,dxdy$$

The ratio $e = S_x/S_y$ is often used to characterize the elongation of the dye patch.

The variance $S_r^2(t)$ corresponding to the radially symmetric distribution C(r,t) is given by:

$$S_r^2\,(t) = \frac{\int_o^\infty r^2\,C(r,t)\,2\pi r\,dr}{\int_o^\infty C(r,t)\,2\pi r\,dr}$$

It should be noted that only horizontal integrations of the mean vertical distributions were carried out. In several cases the thickness as well as the vertical concentration distribution varied considerably within the patch. A more representative way of calculating the variances would be to carry out such calculations in future. The calculated variances for all experiments are summarized in Tables 3 and 4.

Having calculated the variances of the observed concentration distributions, the diffusion parameters, namely eddy diffusivities and length scales were then computed by the widely accepted practice (for example, see Okubo 1971, Murthy 1970, 1973 and others). By definition,

Surface Layer Experiments

Table 3. Calculated Variance (CM^2) and Elongation $e=S_x/S_y$

Expt. #	Diffusion Time (Sec.) t	Longitudinal S_x^2	Transverse S_y^2	Elongated Patch $S_{xy}^2 = S_x^2 + S_y^2$	Radial Symmetry S_r^2	Elongation $e = \frac{S_x}{S_y}$
ES1	$1.2x10^4$ (3.5 h)	$8.01x10^7$	$1.36x10^7$	$9.38x10^7$	$5.7x10^7$	2.43
ES2	$1.1x10^5$ (30 h)	$1.01x10^{11}$	$2.07x10^{10}$	$1.21x10^{11}$	$8.32x10^{10}$	2.21
ES3	$3.69x10^4$ (10 h)	$9.40x10^9$	$1.468x10^9$	$1.09x10^{10}$	$5.28x10^9$	2.53
	$5.31x10^4$ (15 h)	$1.74x10^{10}$	$3.03x10^9$	$2.04x10^{10}$	$1.07x10^{10}$	2.40
	$1.22x10^5$ (33 h)	$2.04x10^{10}$	$1.66x10^{10}$	$3.82x10^{10}$	$2.94x10^{10}$	1.14
	$2.09x10^5$ (60 h)	$3.20x10^{11}$	$1.60x10^{11}$	$4.80x10^{11}$	$3.71x10^{11}$	1.41
ES4	$1.37x10^4$ (4 h)	$1.81x10^8$	$1.41x10^7$	$1.94x10^8$	$3.02x10^7$	3.60
ES5	$2.16x10^4$ (6 h)	$7.87x10^8$	$2.12x10^8$	$9.97x10^8$	$5.12x10^8$	1.93
ES6	$2.52x10^4$ (7 h)	$2.01x10^9$	$1.52x10^8$	$2.16x10^9$	$6.92x10^8$	3.63
	$9.36x10^4$ (26 h)	$1.35x10^{10}$	$3.65x10^9$	$11.71x10^{10}$	$7.87x10^9$	1.92
	$1.91x10^5$ (53 h)	$7.44x10^{10}$	$2.82x10^{10}$	$1.03x10^{11}$	$8.28x10^{10}$	1.63

Deep Water Experiments

Table 4. Calculated Variance (CM^2) and Elongation $e=S_x/S_y$

Expt. # Date	Diffusion Time (Sec.) t	Longitudinal S_x^2 (CM^2)	Transverse S_y^2 (CM^2)	Elongated Patch $S_{xy} = S_x^2 + S_y^2$	Radial Symmetry S_r^2 (CM^2)	Elongation $e = \frac{S_x}{S_y}$
ED1	4.3×10^4 (12 hr)	1.1×10^8	4.6×10^7	1.56×10^8	8.3×10^7	1.55
	1.2×10^5 (33 hr)	6.3×10^8	2.1×10^8	8.4×10^8	4.0×10^8	1.73
	1.8×10^5 (49 hr)	1.2×10^9	4.3×10^8	1.63×10^9	4.9×10^8	1.67
	2.7×10^5 (74 hr)	4.0×10^9	4.3×10^8	4.43×10^9	1.5×10^9	3.05
ED2	5.8×10^4 (16 hr)	5.8×10^7	2.7×10^7	8.5×10^7	4.8×10^7	1.47
	7.2×10^4 (20 hr)	1.3×10^8	2.1×10^7	1.51×10^8	8.3×10^7	2.49
ED3	3.1×10^4 (8.5 hr)	5.9×10^7	2.1×10^7	8.0×10^7	4.6×10^7	1.68
	9.4×10^4 (26 hr)	6.9×10^7	1.8×10^7	8.7×10^7	6.0×10^7	1.96
	1.4×10^5 (40 hr)	2.2×10^8	4.8×10^7	2.68×10^8	1.6×10^8	2.14
ED4	1.2×10^5 (32 hr)	1.0×10^8	3.7×10^7	1.37×10^8	4.6×10^7	1.64
ED5	1.3×10^4 (3.5 hr)	4.2×10^8	8.4×10^7	5.04×10^8	3.4×10^8	2.24
	2.2×10^4 (6 hr)	5.1×10^8	2.4×10^8	7.5×10^8	6.0×10^8	1.46
ED6	4.3×10^4 (12 hr)	2.5×10^8	1.0×10^8	3.5×10^8	2.5×10^8	1.58
	6.1×10^4 (17 hr)	6.0×10^8	2.5×10^8	8.5×10^8	6.8×10^8	1.55
	1.5×10^5 (41 hr)	2.3×10^9	7.0×10^8	3.0×10^9	2.3×10^9	1.81
	2.5×10^5 (68 hr)	3.7×10^9	8.5×10^8	4.55×10^9	3.4×10^9	2.09

Eddy diffusivities for one-dimensional case

$$K_x = \frac{S_x{}^2}{2t}, \quad K_y = \frac{S_y{}^2}{2t}$$

or for two-dimensional case

$$K_{xy} = \frac{S_{xy}{}^2}{4t}; \quad K_r = \frac{S_r{}^2}{4t}$$

where t is the diffusion time.

The length scale is usually defined as a factor (usually 3) times the standard deviation of the observed concentration distribution. The computed diffusivities and the corresponding length scales are summarized in Tables 5 and 6.

It is customary to interpret diffusion data and results from field experiments by constructing certain basic diffusion diagrams (for example Stommel 1949, Okubo 1971). One such diagram conventionally used is a plot of an effective diffusivity versus length scale elucidating the dependence of diffusion on turbulence structure. A typical logarithmic plot of eddy diffusivity versus the corresponding length scale is shown in Figure 8. As pointed out earlier, a very wide spectrum of horizontal motions exists in the lakes, thus the horizontal eddy diffusivity usually increases with the scale of mixing considered. As expected, however, the deep water values are one-two orders of magnitude smaller than those of the surface layer values. A plausible explanation for the smaller values at deeper depths can be understood on the reasonable assumption that the available turbulent energy for diffusion decreases with depth.

Observed results of dye patch diffusion experiments have often been interpreted with predictions of the similarity theory of turbulence. Following the arguments of similarity theory of turbulence, it is easy to show that the eddy diffusivity grows as "4/3 power" of the scale of diffusion:

$$K = c' \varepsilon^{1/3} \ell^{4/3}$$

where c is a numerical constant.

The basic concept involved in the formulation of "4/3 power law" is that the eddies responsible for the horizontal spread of substance are locally isotropic and homogeneous lying in the "inertial subrange". The properties of these eddies thus depend only on the rate of energy transfer through the range if a statistical equilibrium is established.

In Figure 8 we attempt to fit the "4/3 power law" to the diffusivity and the following regression equations were determined from the data:

$$(K_{xy}\text{: cm}^2\ \text{sec}^{-1};\ \ell_{xy}\text{:ccm})$$

Surface Layer Experiments

Table 5. Calculated Length Scales and Eddy Diffusivities

Expt. #	Diffusion Time (Sec.)	Length Scales (CM)				Eddy Diffusivities (CM^2SEC^{-1})				
	t	L_x	L_y	L_{xy}	L_r	K_x	K_y	K_{xy}	K_r	K_x/K_y
ES1	$1.2x10^4$ (3.5 h)	$2.7x10^4$	$1.1x10^4$	$2.9x10^4$	$2.7x10^4$	$3.3x10^3$	$5.7x10^2$	$2.0x10^3$	$1.2x10^3$	5.79
ES2	$1.1x10^5$ (30 h)	$9.5x10^5$	$4.3x10^5$	$1.1x10^6$	$8.7x10^5$	$4.6x10^5$	$9.4x10^4$	$2.8x10^5$	$1.9x10^5$	4.89
ES3	$3.69x10^4$ (10 h)	$2.91x10^5$	$1.15x10^5$	$3.13x10^5$	$2.18x10^5$	$1.27x10^5$	$1.99x10^4$	$7.39x10^4$	$3.58x10^4$	6.38
	$5.31x10^4$ (15 h)	$3.96x10^5$	$1.65x10^5$	$4.28x10^5$	$3.1x10^5$	$1.64x10^5$	$2.85x10^4$	$9.6x10^4$	$5.04x10^4$	5.75
	$1.22x10^5$ (33 h)	$4.29x10^5$	$3.87x10^5$	$5.86x10^5$	$5.15x10^4$	$8.36x10^4$	$6.8x10^4$	$7.83x10^4$	$6.02x10^4$	1.23
	$1.09x10^5$ (60 h)	$1.7x10^6$	$1.2x10^6$	$2.08x10^6$	$1.83x10^6$	$7.66x10^5$	$3.83x10^5$	$5.74x10^5$	$4.44x10^5$	2.00
ES4	$1.37x10^4$ (4 h)	$4.04x10^4$	$1.13x10^4$	$4.18x10^4$	$1.65x10^4$	$6.6x10^3$	$5.15x10^2$	$3.54x10^3$	$5.5x10^2$	12.82
ES5	$2.16x10^4$ (6 h)	$8.4x10^4$	$4.36x10^4$	$9.5x10^4$	$6.79x10^4$	$1.82x10^4$	$4.9x10^3$	$1.15x10^4$	$5.93x10^3$	3.71
ES6	$2.52x10^4$ (7 h)	$1.35x10^5$	$3.7x10^4$	$1.39x10^5$	$7.89x10^4$	$4.0x10^4$	$3.0x10^3$	$2.14x10^4$	$6.87x10^3$	13.33
	$9.36x10^4$ (26 h)	$3.49x10^5$	$1.8x10^5$	$3.92x10^5$	$2.66x10^5$	$7.2x10^4$	$1.95x10^4$	$4.57x10^4$	$2.1x10^4$	3.69
	$1.9x10^5$ (53 h)	$8.2x10^5$	$5.04x10^5$	$9.63x10^5$	$8.63x10^5$	$1.95x10^5$	$7.4x10^4$	$1.35x10^5$	$1.08x10^5$	2.64

Deep Water Experiments

Table 6. Calculated Length Scales and Eddy Diffusivities

Expt. #	Diffusion Time (Sec.)	Length Scales (CM)				Eddy Diffusivities (CM^2SEC^{-1})				
	t	L_x	L_y	L_{xy}	L_r	K_x	K_y	K_{xy}	K_r	K_x/K_y
ED1	$4.3x10^4$ (12 h)	$3.15x10^4$	$2.03x10^4$	$3.75x10^4$	$2.73x10^4$	$1.28x10^3$	$4.35x10^2$	$9.07x10^2$	$4.83x10^2$	2.94
	$1.2x10^5$ (33 h)	$7.53x10^4$	$4.35x10^4$	$8.69x10^4$	$6.00x10^4$	$2.63x10^3$	$8.75x10^2$	$1.75x10^3$	$8.33x10^2$	3.01
	$1.8x10^5$ (49 h)	$1.04x10^5$	$6.22x10^4$	$1.21x10^5$	$6.64x10^4$	$3.33x10^3$	$1.19x10^3$	$2.26x10^3$	$6.81x10^2$	2.80
	$2.7x10^5$ (74 h)	$1.90x10^5$	$6.22x10^4$	$2.00x10^5$	$1.16x10^5$	$7.41x10^3$	$7.69x10^2$	$4.10x10^3$	$1.39x10^3$	9.31
ED2	$5.8x10^4$ (16 h)	$2.28x10^4$	$1.56x10^4$	$2.77x10^4$	$2.08x10^4$	$5.00x10^2$	$2.33x10^2$	$3.66x10^2$	$2.07x10^2$	2.15
	$7.2x10^4$ (20 h)	$3.42x10^4$	$1.37x10^4$	$3.69x10^4$	$2.73x10^4$	$9.03x10^2$	$1.46x10^2$	$5.24x10^2$	$2.88x10^2$	6.18
ED3	$3.1x10^4$ (8.5h)	$2.30x10^4$	$1.37x10^4$	$2.68x10^4$	$2.03x10^4$	$9.52x10^2$	$3.39x10^2$	$6.45x10^2$	$3.71x10^2$	2.81
	$9.4x10^4$ (26 h)	$2.50x10^4$	$1.27x10^4$	$2.80x10^4$	$2.32x10^4$	$3.67x10^2$	$9.57x10^1$	$2.31x10^2$	$1.60x10^2$	3.83
	$1.4x10^5$ (40 h)	$4.45x10^4$	$2.08x10^4$	$4.91x10^4$	$3.79x10^4$	$7.86x10^2$	$1.71x10^2$	$4.79x10^2$	$2.86x10^2$	4.60
ED4	$1.2x10^5$ (32 h)	$3.00x10^4$	$1.82x10^4$	$3.51x10^4$	$2.03x10^4$	$4.17x10^2$	$1.54x10^2$	$2.85x10^2$	$9.58x10^1$	2.71
ED5	$1.3x10^4$ (3.5h)	$6.15x10^4$	$2.75x10^4$	$6.73x10^4$	$5.53x10^4$	$1.62x10^4$	$3.23x10^3$	$7.69x10^3$	$6.54x10^3$	5.02
	$2.2x10^4$ (6 h)	$6.77x10^4$	$4.65x10^4$	$8.2x10^4$	$7.35x10^4$	$1.16x10^4$	$5.45x10^3$	$8.52x10^3$	$6.82x10^3$	2.13
ED6	$4.3x10^4$ (12 h)	$4.74x10^4$	$3.00x10^4$	$5.61x10^4$	$4.74x10^4$	$2.91x10^3$	$1.16x10^3$	$2.03x10^3$	$1.45x10^3$	2.51
	$6.1x10^4$ (17 h)	$7.3x10^4$	$4.74x10^4$	$8.75x10^4$	$7.82x10^4$	$4.92x10^3$	$2.05x10^3$	$3.48x10^3$	$2.79x10^3$	2.40
	$1.5x10^5$ (41 h)	$1.44x10^5$	$7.94x10^4$	$1.64x10^5$	$1.44x10^5$	$7.67x10^3$	$2.33x10^3$	$5.00x10^3$	$3.83x10^3$	3.29
	$2.5x10^5$ (68 h)	$1.82x10^5$	$8.75x10^4$	$2.02x10^5$	$1.75x10^5$	$7.4x10^3$	$1.70x10^3$	$4.55x10^3$	$3.40x10^3$	4.35

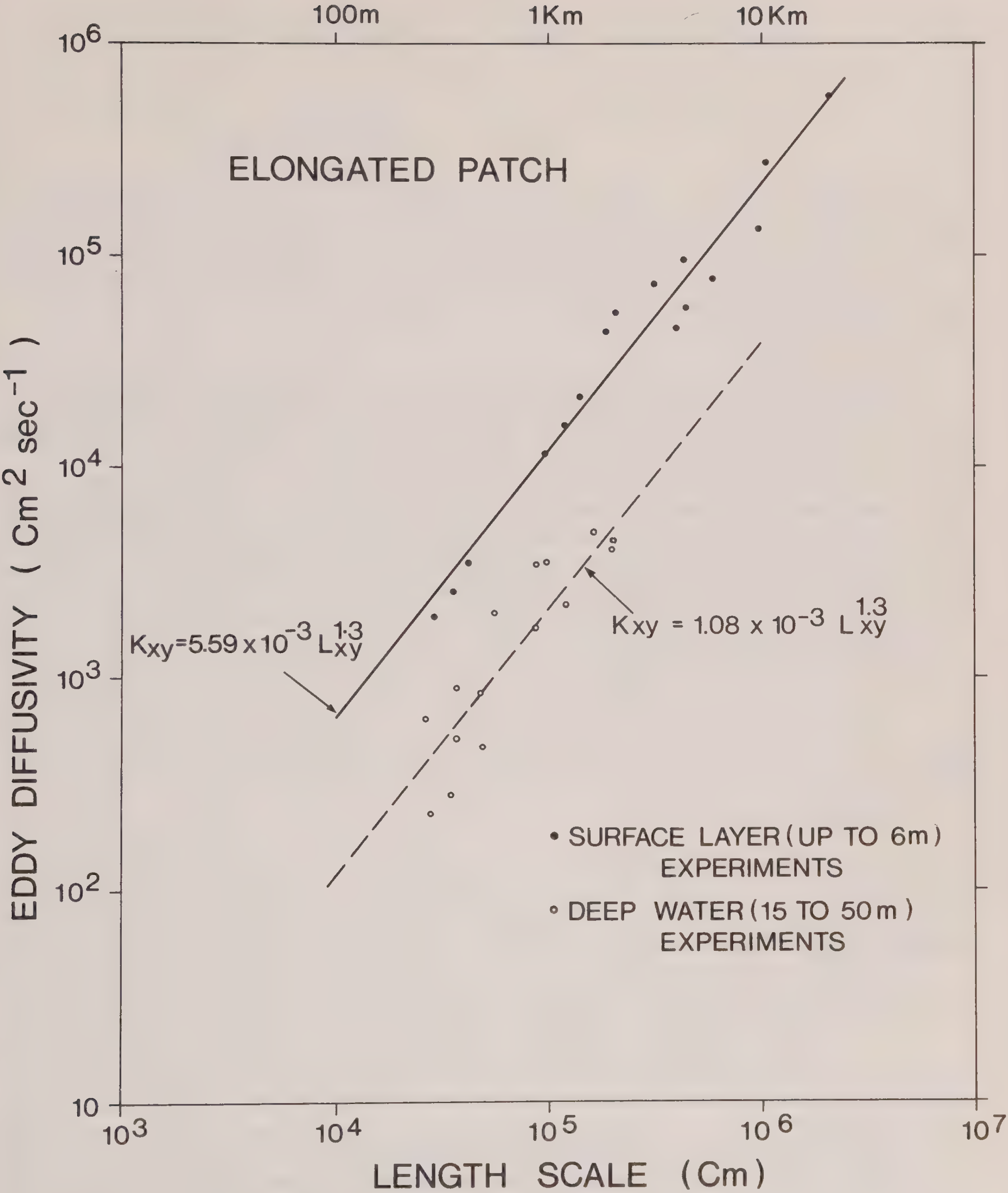

Figure 8. Horizontal eddy diffusivity.

$$K_{xy} = 5.6 \times 10^{-3} \; \ell_{xy}^{1.3} \qquad \text{Epilimnion experiments}$$

$$K_{xy} = 1.1 \times 10^{-3} \; \ell_{xy}^{1.3} \qquad \text{Thermocline and Hypolimnion experiments}$$

In order that the results of the similarity theory of turbulence apply to the diagram, all that is required is that ε decreases with depth in some way. A comparison of the theoretical and regression equations gives $(\varepsilon_s/\varepsilon_d) \approx 125$. The energy dissipation rate at the surface is greater by more than two orders of magnitude compared to the deep water value, a physically acceptable result.

In contrast to the horizontal diffusion, the process of vertical diffusion is controlled primarily by small scale motions characteristic of stably stratified water. The stability in a column of water plays a dominant role in the structure of turbulence in the vertical direction. This suggests that the vertical diffusivity, K_z, should depend on a stability parameter (say Richardson's number). Although several semi-empirical relations between K_z and Richardson number have been proposed in the literature (for example, Munk and Anderson, 1948; Mamayev, 1958 and others) a comprehensive theory is not in sight. Following Bowden (1960), Kullenberg (1971) proposed the following relation, to interpret vertical diffusion data obtained in Oceanic experiments:

$$K_z = \alpha \frac{\overline{W^2}}{\overline{N^2}} \left|\frac{dq}{dz}\right|$$

where $\overline{W^2}$ is the mean-square of the wind speed (proportional to wind stress) $\overline{N^2}$ is the mean stratification parameter defined by $N^2 = \frac{g}{\bar{\rho}} \frac{\partial \bar{\rho}}{\partial z}$ (sec $^{-2}$) and $\bar{\rho}$ and $\frac{d\bar{\rho}}{dz}$ are the mean density and mean density gradient of the water column. $\left|\frac{dq}{dz}\right|$ is the absolute value of the vertical current shear defined by

$$\left|\frac{dq}{dz}\right| = \left\{ \left(\frac{du}{dz}\right)^2 + \left(\frac{dv}{dz}\right)^2 \right\}^{1/2} \quad (\text{sec}^{-1})$$

(u,v) are the N-S and E-W components of the current vector q and α is a numerical constant.

This relation can be justified theoretically by assuming that the turbulence is shear generated and that the rate of generation of turbulent energy per unit volume is balanced by the rate of increase in potential energy per unit volume due to vertical mixing. The success of such a simple relationship to interpret vertical diffusion data obtained in fjords, coastal zones and open oceans encouraged us to test its validity from vertical diffusion data collected in Lake Ontario experiments.

The vertical diffusivity was calculated from the vertical concentration distributions C(z). A measure of the vertical mixing is the variance of the concentration distribution defined by,

$$S_z^{\,2} = \frac{\int z^2 \; C(z)dz}{\int C(z)dz}$$

for the central areas of the dye patch.

A measure of the vertical mixing coefficient is given by

$$K_z = S_z^{\,2} \; / \; 2t$$

The measured wind data, temperature and current profiles were used to determine the wind stress, the stability parameter, $\overline{N^2}$ and the absolute value of the vertical current shear $\left|\frac{dq}{dz}\right|$ respectively. These calculations have been performed for a number of layers in all experiments and the computed results are summarized in Table 7. The diffusion characteristic constructed from these calculations is shown in Fig. 9 along with some oceanic data shown for comparative purposes. The numerical value of the constant α is 2×10^{-8} as obtained from a least square analysis of Lake Ontario data. From an analysis of oceanic vertical diffusion data in the top 20 meters, Kullenberg (1971) estimated to be 8×10^{-8}. The lower value of α is attributed to the fact that Lake Ontario experiments are performed at deeper depths (50m or so) usually well below the thermocline. Nevertheless, the relationship is well defined and clearly shows the influence of the wind stress, the density stratification and vertical current shear on the vertical mixing.

Conclusions

The present analysis follows the theoretical arguments of the similarity theory turbulence, particularly the inertial subrange characterized by the energy dissipation rate, and shear diffusion theories. It is obvious that neither the characteristics of the inertial subrange turbulence nor the characteristics of the shear diffusion mechanism are satisfied during dye patch diffusion experiments over such wide range of time and spatial scales. Although the diffusion characteristics cannot be justified entirely from theoretical arguments, they could be viewed as purely statistical (or parameterization) since they have been constructed from experimental data obtained in widely varying environmental conditions. In a statistical sense, the dependence of the effective diffusivities on the environmental parameters governing the diffusion process provides useful guidelines for modelling practical diffusion problems.

Table 7. Vertical Diffusion Coefficient K_2, Mean Vertical Shear, Mean Stratification, Mean Wind and Parameter $\overline{W^2N^{-2}}\ |dq/dz|$

EXPT. #	DEPTH INTERVAL (m)	K_z (cm^2/sec)	$\|\frac{dq}{dz}\| \cdot 10^3$ (sec^{-1})	$N^2 10^6$ (sec^{-2})	$(W^2)^{1/2}$ (m/sec)	$\overline{W^2N^{-2}}\ \|\frac{dq}{dz}\|$ (cm^2/sec)
ED1	19–21	0.1	12.4	150	4.2	$1.4 \cdot 10^7$
ED2	35–45	0.5	4.0	2.3	2.7	$1.3 \cdot 10^8$
ED3	33–40	0.2	4.0	12	3.3	$3.7 \cdot 10^7$
ED4	20–35	0.1	5.2	36	4.3	$2.7 \cdot 10^7$
ED5	20–25	0.4	19	450	7.0	$2.0 \cdot 10^7$
	35	0.05	(2.7)	320	6.2	$(3.2 \cdot 10^6)$
ED6	15–35	22	15	26	12.2	$8.7 \cdot 10^8$
	20–23	2.2	10.5	62	11.3	$2.2 \cdot 10^8$
	25–45	3.8	2.9	8	6.0	$1.3 \cdot 10^8$
	25–35	0.5	2.9	3.7	4.3	$1.4 \cdot 10^8$

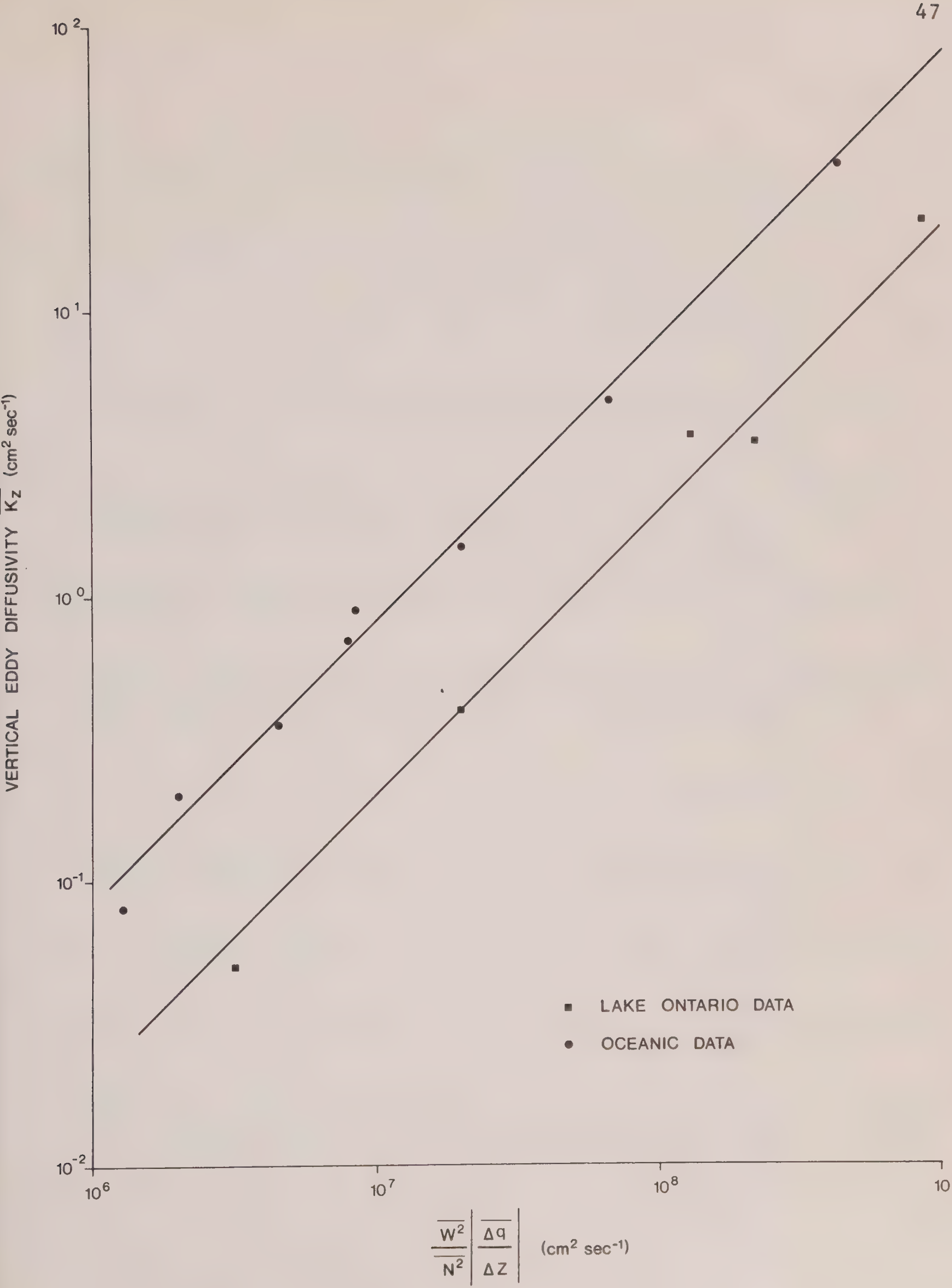

Figure 9. Vertical eddy diffusivity.

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Elder, F.C., and B. Brady, "A Meteorological Buoy System for Great Lakes Studies," Canada Centre for Inland Water Technical Bulletin No. 71, 1972, pp. 11.

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UNITED STATES

Editors	Fred Jenkins and May Laughrun
Typing	Robert E. Massey

COMMENTS BY THE U.S. DIRECTOR

This issue covers IFYGL activities from October 1 to December 31, 1973 (fig. 1). Some reports on later events are included.

Data management activities continue to receive major emphasis, and will be discussed in greater detail in the next issue of the IFYGL Bulletin. As of March 1974 the following data sets have been processed:

- The Physical Data Collection System (PDCS) Provisional Data Base for May, July, and October 1972.

- Provisional data for all 59 ship cruises on a 1-s cycle for individual cruises; provisional on-station surface and EBT data for all cruises.

- Provisional rawinsonde data for two 6-day periods.

A U.S. IFYGL Archive Plan has been developed and will be implemented jointly by CEDDA and the National Climatic Center (NCC) of EDS, NOAA.

Frank Quinn, Lake Survey Center, NOAA, has accepted the appointment as U.S. Project Leader for the IFYGL Evaporation Synthesis Project, replacing E.M. Rasmusson of CEDDA.

The IFYGL Technical Manual No. 4, "U.S. IFYGL Participation Data Acquisition System," was printed in December 1973. Anyone who did not receive a copy and desires one can request it from:

U.S. IFYGL Project Office
NOAA - EM-7
6010 Executive Blvd.
Rockville, Md. 20852

Plans for the IFYGL Scientific Report series are progressing. At the Joint Management Team meeting on January 10, 1974, agreement was reached on an initial list of international summary IFYGL Scientific Reports. It is anticipated that these reports will be published between 1975 and 1977, as the major scientific analyses are completed. The initial list is as follows:

1. Title: The Terrestrial Water Budget of Lake Ontario and the Ontario Basin.
   Principal authors: B.G. DeCooke and D.F. Witherspoon

2. Title: Lake Meteorology and the Atmospheric Water Balance.
   Principal authors: J.A.W. McCulloch, E.M. Rasmusson, and H.L. Ferguson.

3. Title: The Energy Balance of Lake Ontario.
   Principal authors: A.P. Pinsak and G.K. Rodgers.

4. Title: Evaporation Synthesis.
   Principal authors: J.A.W. McCulloch and E.M. Rasmusson.

5. Title: Biology and Chemistry.
   Principal authors: W.J. Christie and N. Thomas.

6. Title: Water Movements.
   Principal authors: E.B. Bennett and J.H. Saylor.

7. Title: The Atmospheric Boundary Layer.
   Principal authors: F.C. Elder and J.Z. Holland.

8. Title: The IFYGL Program.
   Principal authors: E.J. Aubert and T.L. Richards.

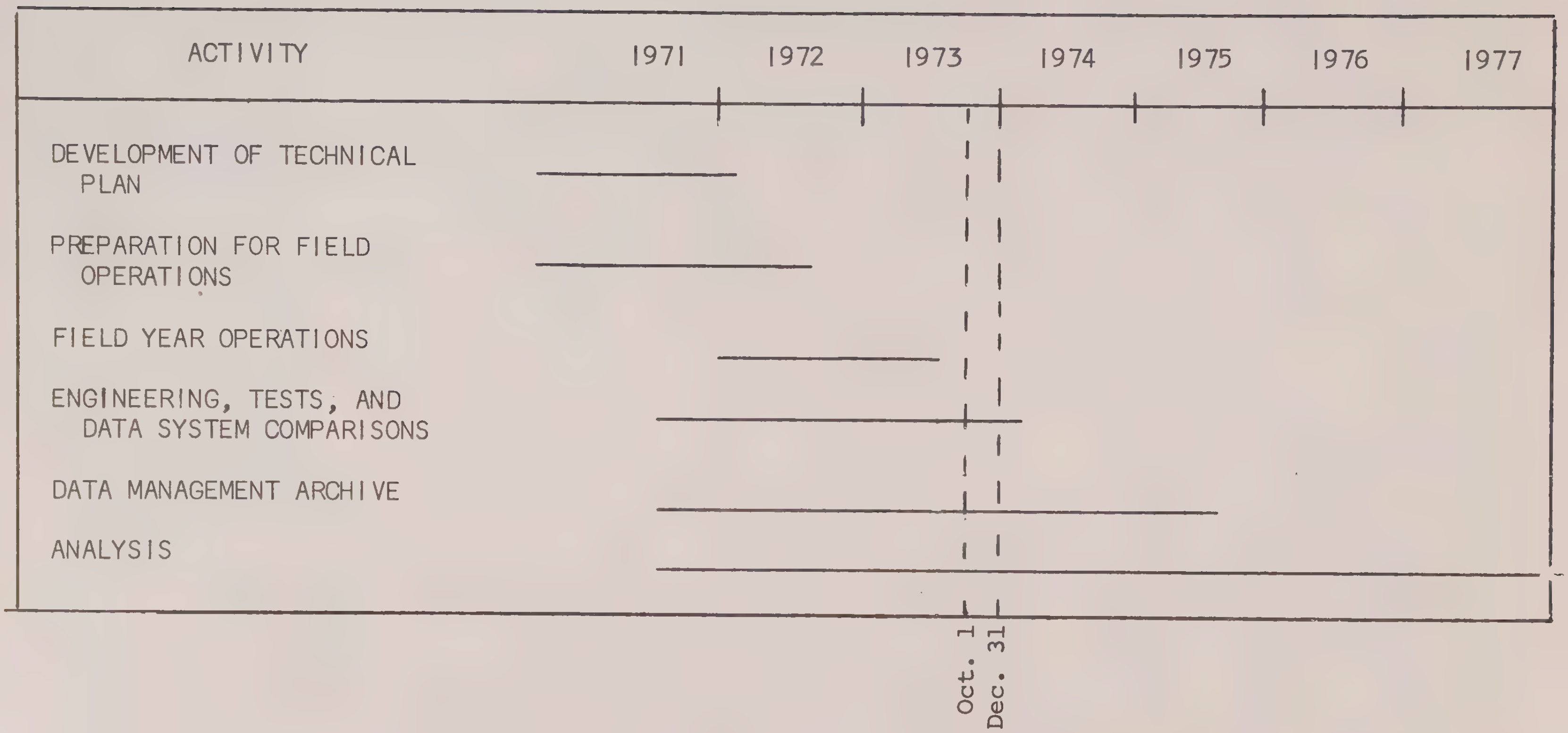

Figure 1.--U.S. IFYGL schedule.

U.S. SCIENTIFIC PROGRAM

Based upon reports requested by the U.S. IFYGL Project Office, the progress from October 1 through December 31, 1973, is presented for each of the U.S. IFYGL tasks. Some reports cover work done in January 1974.

Project area status reports follow the task reports.

Tasks

1. *Phosphorus Release and Uptake by Lake Ontario Sediments*

Principal Investigators: D. Armstrong and R.F. Harris - University of Wisconsin

Between October 9 and 12, 1973, two or more sediment core samples were obtained from IFYGL sampling stations 10, 14, 30, 41, 62, 60, 75, 92, 96, 45, 34, and at the mouth of the Genesee River. The first 15 cm of one core from each station was subdivided into 3-cm sections, and each sediment section immediately squeezed with a pressure membrane device to obtain the interstitial water. An effort was made to maintain the original sediment temperature and oxidation potential during the squeezing process. The interstitial water was subsequently analyzed for inorganic P and total Fe. Dissolved inorganic P concentration was also determined for the lake water just above the sediment-water interface. Another core from each station was divided into 5-cm sections and stored under nitrogen in glass jars for laboratory experiments to determine the amounts of inorganic P desorbed from Lake Ontario sediments. These experiments involved successive equilibrations of sediment suspended in a 0.1 M NaCl solution under a nitrogen atmosphere. Extra cores were obtained at several stations for the purpose of evaluating the squeezing technique used in obtaining interstitial water. Evaluation of experimental results of this and other phases of the research continued in preparation for publication.

2. *Net Radiation*

Principal Investigator: M.A. Atwater - CEM

Work on developing a technique to diagnose middle cloud amount and high cloud amount for application during periods of extensive low overcast was completed. Regression equations were derived to diagnose upper cloud amount from an overall sample of 597 cases. Potential predictors included relative humidity at 50-mb levels; gradients of relative humidity; maximum, minimum, and averaged values of relative humidity in vertical layers; temperature at 50-mb levels; and temperature lapse rates. Regression equations were derived for (a) the entire sample, (b) samples at 0000 GMT and 1200 GMT, and (c) a warm and cold season. Development of the data sample and results will be written up in detail.

Results showed that the diagnosed value of middle cloud amount was within 30 percent cloud cover of the observed value in almost 80 percent of the cases (rms error = 24 percent). Reductions in errors by inclusion of (b) and (c) above were not sufficiently large to justify use of more than one regression equation.

In diagnosing high cloud amount, the rms error was about 4 percent greater than for middle cloud amount. Comparison with results obtained under the assumption of clear or overcast conditions, or the climatological average value for the year, demonstrated the effectiveness of the diagnostic technique. Observations on the *Researcher* and *Advance II* for May, June, and July 1972 were received. These data have been processed, with location information added. The basic data sample for these months is being revised to include the new data.

A computer program has been written and checked out to obtain the information required for developing a technique to diagnose the presence of fog during the spring season. The variables computed include average visibilities from land stations and ships and their ratio; lowest land-observed visibility; average and lowest dewpoint at land stations; average wind speed; average low cloud amount; and difference between lake surface temperature and average land temperature. This computer program will be used with the revised spring data sample to develop a fog diagnostic technique.

The quality of the ESSA-9 photographs for October 1972 seem to be inadequate for refining cloud analyses over the lake. NOAA-2 photographs for November 1972 will be examined to determine whether they can prove more useful.

Study of observed and computed solar radiation for Brockport, N.Y., showed that the largest differences occurred in winter when there was snow cover. The solar radiation model will be revised to take into account instances of a high surface albedo. A study for the Geneva Research Farm yielded results similar to those for Brockport. The observed and computed weekly average insolation and cloud cover are shown in figure 2, and the daily observed and computed insolation are given in figure 3. A paper describing the solar radiation model and the Brockport results appears in the March 1974 issue of Journal of Applied Meteorology.

Radiative heating rates for October 1 through December 10, 1972, have been computed and will soon be stored on punchcards. When documentation has been completed, the cards will be sent to the IFYGL Data Center.

3. *RFF/DC-6 Boundary Layer Fluxes*

Principal Investigator: B.R. Bean - ERL/NOAA

During the IFYGL alert periods in 1972, the NOAA Research Flight Facility DC-6 instrumented (gust probe) aircraft was used to measure the turbulent

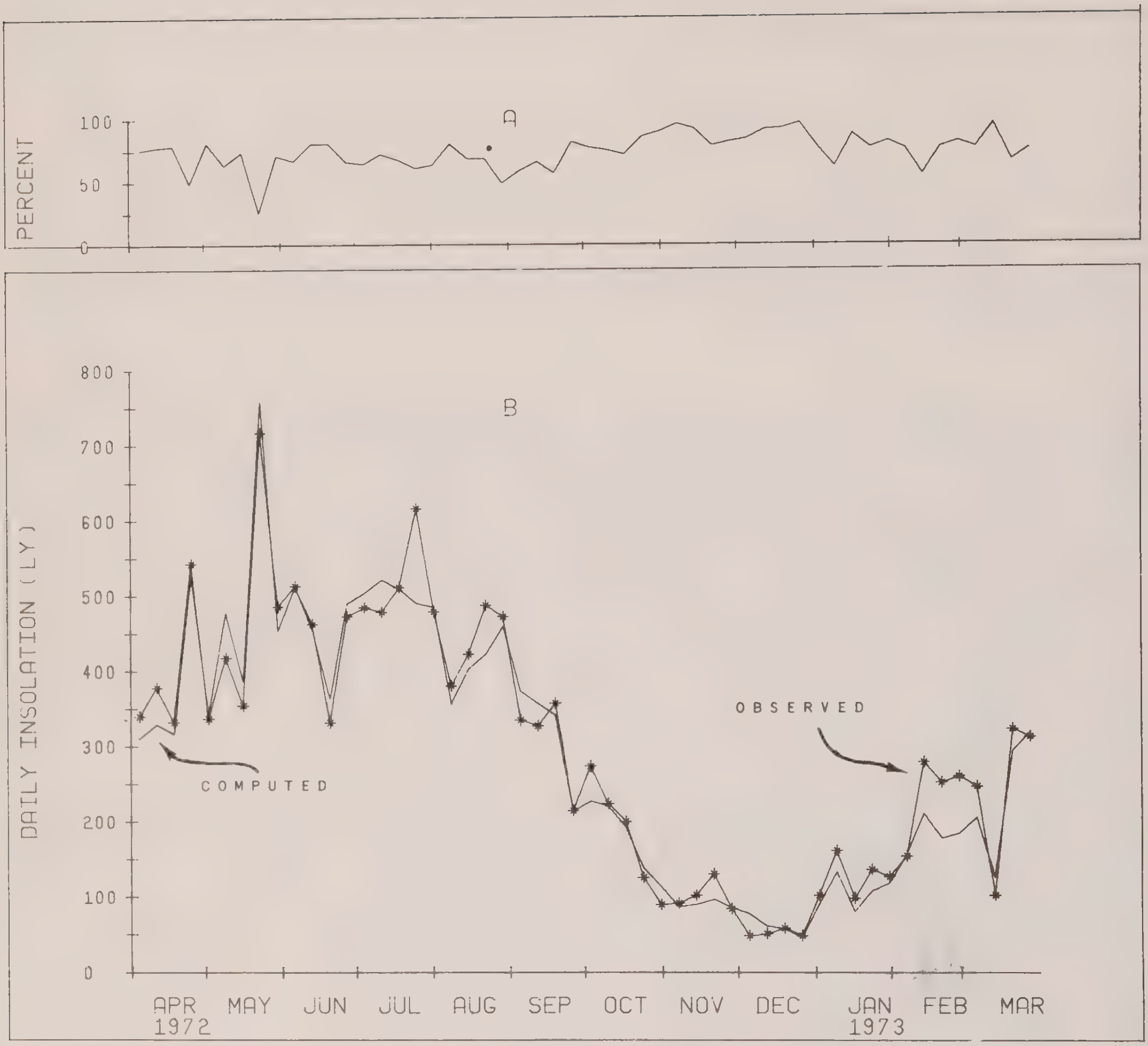

Figure 2.--Average weekly cloud cover, A, and daily insolation, B, for Geneva Research Farm, N.Y.

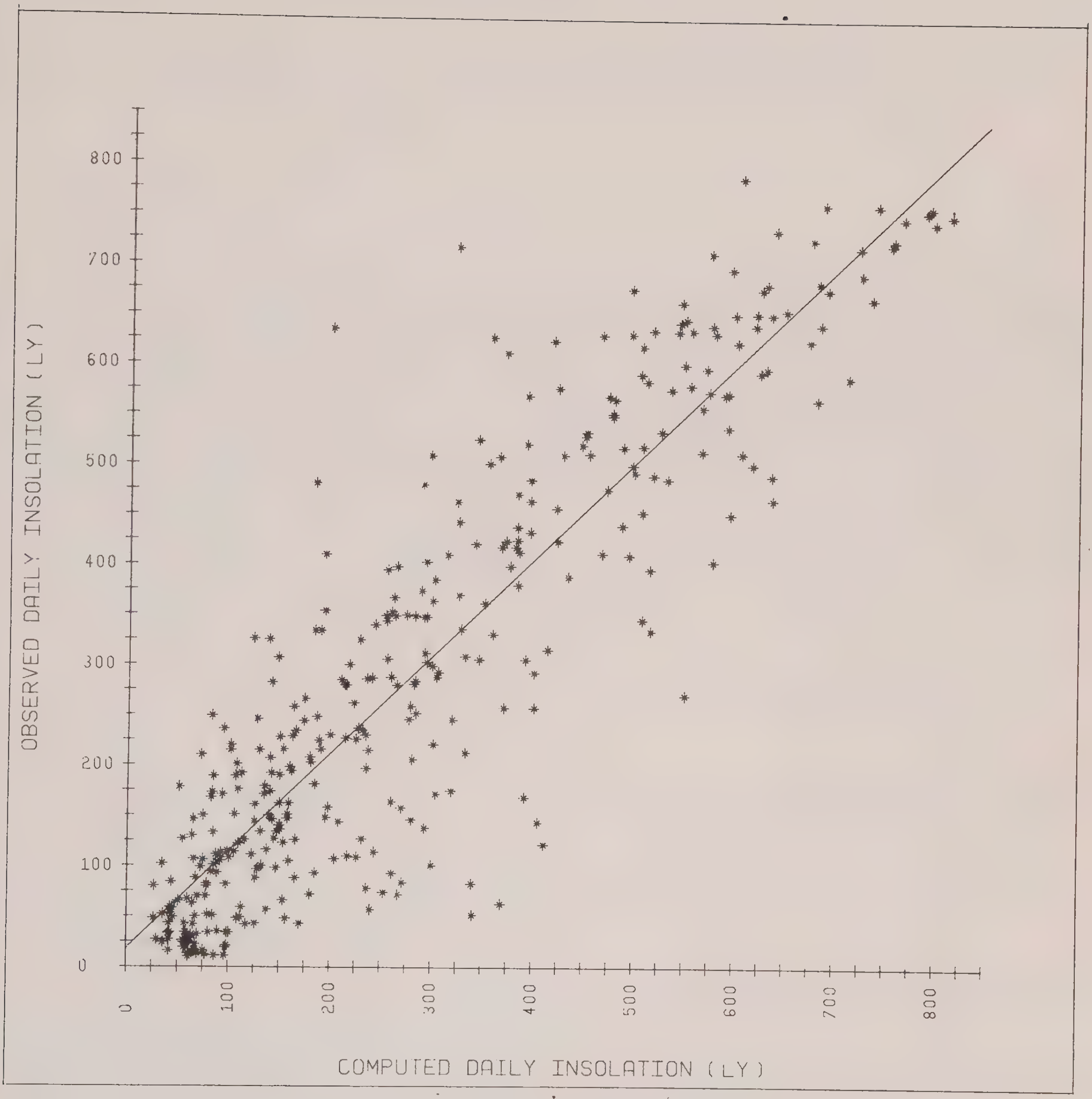

Figure 3.--Scatter diagram for Geneva Research Farm, N.Y.

fluxes of heat, momentum, and water vapor at heights ranging from 20 to 300 m above the lake surface. With working programs available for the reduction of the gust-probe data, 17 days in the period May through November were selected for analysis of the following:

(a) Time series records of the turbulent fluctuations of u', v', w', T' and ρ_w'.

(b) Mean values of u, v, w, T, and ρ_w, and their flux quantities.

(c) Spectra of u', v', w', T', and ρ_w', and their flux quantities.

The turbulent flux quantities were constructed by the eddy correlation technique from the time-series records of wind, temperature, and water vapor. The corresponding spectra were then obtained for 3-min sampling lengths, which, at the aircraft's speed of ∿92 m/s, represents flight paths of ∿16.7 km. This was done for both along-wind and crosswind flight patterns. The cross spectra and the time-series records allow us to speculate on possible modes of water vapor transport over limited fetch, and to relate these to atmospheric stability and the state of the lake surface. Detailed results will be presented at the AGU/AMS meeting in April 1974, as well as at the IAGLR Seventeenth Annual Conference in August 1974.

4. *Nitrogen Fixation*

Principal Investigator: R. Burris - University of Wisconsin

No report.

5. *Profile Mast and Tower Program*

Principal Investigator: J.A. Businger - University of Washington

No report.

6. *Status of Lake Ontario Fish Populations*

Principal Investigator: J.H. Kutkuhn[1] - Great Lakes Fisheries Laboratory

Offshore Stocks:

Computer summaries of all survey data have been completed and are being used, together with all acoustical records, in plotting the distribution and

[1] J.H. Kutkuhn has replaced J.F. Carr as Principal Investigator.

estimating the size of forage stocks. Complementary work on the biology of important Lake Ontario fishes is underway. Included are studies of the comparative growth of alewives in Lake Ontario and the other Great Lakes, food and feeding relationships among alewives, smelt, and sculpins; and the contribution of invertebrates to the maintenance of Lake Ontario fish populations. A manuscript entitled "Cooperative Survey of Offshore Fish Stocks in Lake Ontario during the 1972 International Field Year for the Great Lakes (IFYGL) " is in final preparation.

Inshore Stocks:

Analysis of survey data is complete. "An Annotated List of the Fishes of the Lake Ontario Watershed" is nearing completion, in which over 130 individual species are listed, with a summary of the origin, distribution, abundance and economic importance of each species. "A Checklist of the Fishes of the Lake Ontario Watershed" is being prepared in cooperation with the Royal Ontario Museum, and another report, "Recent History of the U.S. Commercial Fisheries," is a joint effort by the New York Department of Environmental Conservation and the Bureau of Sport Fisheries and Wildlife. Other studies underway deal with the biology of white perch, yellow perch, and rock bass.

7. *Material Balance of Lake Ontario*

Principal Investigator: D.J. Casey - EPA

No report.

8. *Runoff*

Principal Investigator: L.T. Schutze - U.S. Army Corps of Engineers

Work on this task is complete; first-cut estimates of monthly runoff from lasn areas have been prepared for use in Task 9.

9. *Evaporation (Lake-Land)*

Principal Investigator: L.T. Schutze - U.S. Army Corps of Engineers

First-cut estimates for the Field Year were completed and furnished to the Steering Committee, Panel Chairmen, and Program Coordinators. Final estimates of monthly evaporation will be made when other terms of the lake equation become available, probably early in Fiscal Year 1975.

10. *Simulation Studies and Analyses Associated With the Terrestrial Water Balance*

Principal Investigator: B.G. DeCooke - U.S. Army Corps of Engineers

Activity has not begun.

11. *Land Precipitation Data Analysis*

Principal Investigators: L.T. Schutze and R. Wilshaw - U.S. Army Corps of Engineers

No progress was made in this quarter. Plans are to begin investigating methods of estimating weekly and monthly precipitation from records of index stations and to use daily precipitation data for the Lake Ontario basin furnished by F.H. Quinn, Principal Investigator on Task 48.

12. *Transport Processes Within the Rochester Embayment of Lake Ontario*

Principal Investigator: W.H. Diment - University of Rochester

No report.

13. *Soil Moisture and Snow Hydrology*

Principal Investigator: W.N. Embree - U.S. Geological Survey

Monthly changes in soil moisture for the Black River Basin have been computed. A report on this study has been prepared and is in review. Moisture content in the unsaturated zone, computed in inches of depth over the basin, ranged from about 51 in April to 37 in August. Raw data will be processed for submission to the IFYGL Data Center.

14. *Boundary Layer Structure and Mesoscale Circulation*

Principal Investigator: M.A. Estoque - University of Miami

See Task 15 below.

15. *Mesoscale Simulation Studies*

Principal Investigator: M.A. Estoque - University of Miami

Major effort was spent in finishing the work on numerical modeling. The two-dimensional model is complete, and simulation of one of the observed lake breezes appears to be quite realistic. The three-dimensional model is not yet complete; we are working on a procedure to establish initial conditions for the model once orographic effects have been incorporated.

16. *Lake Level Transfer Across Large Lake*

Principal Investigator: C.B. Feldscher - LSC/NOAA

Selection of periods of calm water at both the United States and Canadian gages has been completed. Meteorological data have been received from Toronto and from the Rochester weather station, and comparison has been begun of atmospheric pressure and wind differences during the selected periods of calm water.

17. *Nearshore Ice Formation, Growth, and Decay*

Principal Investigator: A. Pavlak - General Electric Company

No report.

18. *Advection Term - Energy Balance*

Principal Investigator: J. Grumblatt - LSC/NOAA

No report.

19. *Occurrence and Transport of Nutrients and Hazardous Polluting Substances in the Genesee River Basin*

Principal Investigator: L.J. Hetling - New York State Department of Environmental Conservation

Water Quality Network:

The last biweekly stream samples were taken during 1 week, beginning on January 6, 1974. Water samples for pesticide-scan and heavy-metals analyses were collected the first week of October 1974. On October 9 and 10, sediment samples were obtained at all the water quality network stations.

Laboratory analyses of samples for the first 13 months have been completed, and the results have been compiled and computerized. Data for the first 10 months have been plotted.

Point Source Network:

The normal biweekly sampling program of the three streams (Avon Creek, Spring Brook, and Fish Creek) was completed at the end of October. During the first week of December, a dye study was run on each of the streams with help from personnel of the U.S. Geological Survey. During the third week of December, 24-hr surveys were carried out at the Holcomb and Avon Trailer Park Sewage Treatment plants. The dye studies and 24-hr surveys will permit adjustment of the stream nutrient discharges for travel time and diurnal fluctuations of the treatment plant discharges.

Data have been tabulated, and are being prepared for computer filing and subsequent analysis. Manual manipulations of the data have been carried out to determine trends and decide on the best procedure for computer analysis. A large amount of data has been hand plotted for visual intercomparisons, Full time will be devoted to finishing the data analysis and working on mathematical modeling.

20. *Boundary Layer Flux Synthesis*

Principal Investigators: J.A. Almazan and J.K.S. Ching[2] - CEDDA/NOAA

The United States and Canadian meteorological buoy and tower data were used for testing the orthogonal function objective analysis technique described in IFYGL Bulletin No. 9. Results show that the space field of a meteorological variable, such as temperature, as well as the statistical confidence of the field can be readily obtained. The technique has been applied to wind components, wind speed, air and lake temperature, and moisture. Crossproducts of wind speed with (a) wind components, (b) air-lake temperature differences, and (c) air-lake moisture differences will be computed during the next quarter for further analysis. A field of a stability parameter will also be analyzed.

21. *Hazardous Material Flow*

Principal Investigator: T. Davies - EPA

No report.

22. *Remote Measurement of Chlorophyll With Lidar Fluorescent System*

Principal Investigator: H.H. Kim - NASA

No report.

23. *Inflow/Outflow Term - Terrestrial Water Budget*

Principal Investigator: I.M. Korkigian - U.S. Army Corps of Engineers

This task has been completed, and the final report submitted to the U.S. IFYGL Data Center.

24. *Use of an Unsteady-State Flow Model To Compute Continuous Flow*

Principal Investigator: I.M. Korkigian - U.S. Army Corps of Engineers

Reduction of discharge measurements at two hydraulic sections on the St. Clair River is about 50 percent complete.

25. *Radiant Power, Temperature, and Water Vapor Profiles Over Lake Ontario*

Principal Investigator: P.M. Kuhn - ERL/NOAA

Work completed.

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[2] J. Ching has been added as a Coprincipal Investigator on this task.

26. *Algal Nutrient Availability and Limitation in Lake Ontario*

Principal Investigator: G.F. Lee[3] - University of Texas at Dallas[4]

Data from the phosphorus availability studies of New York State rainwater, runoff, and tributary samples have been summarized in a report, which is being edited. The nitrogen availability analysis from the long-term incubations of river water has been completed. A report on this analysis remains to be written. The nutrient limitation data from the open-lake and river samples are being compiled. Future work will be concentrated on developing the various field studies into a final report.

27. *Wave Studies*

Principal Investigator: P.C. Liu - LSC/NOAA

No report.

28. *Cloud Climatology*

Principal Investigator: W.A. Lyons - University of Wisconsin, Milwaukee

No report.

29. *Zooplankton Production in Lake Ontario as Influenced by Environmental Perturbations*

Principal Investigator: D.C. McNaught - State University of New York at Albany

No report.

30. *Change in Lake Storage Term - Terrestrial Water Budget*

Principal Investigator: R. Wilshaw - U.S. Army Corps of Engineers

It is estimated that computer programing and data processing will be completed in May 1974.

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[3] IFYGL Bulletin No. 9 was in error in stating that N. Sridharan and W. Cowen were no longer connected with this task. They remain as assistant investigators, and K. Sirisinha has been added as an assistant investigator.

[4] G.F. Lee is now affiliated with the University of Texas at Dallas.

31. *Soil Moisture*

Principal Investigator: L.T. Schutze - U.S. Army Corps of Engineers

Lack of manpower and data from IFYGL investigators on evaporation from land continues to delay the start of this task.

32. *Testing of COE (Corps of Engineers) Lake Levels Model*

Principal Investigator: E. Megerian - U.S. Army Corps of Engineers

No report.

33. *Nearshore Study of Eastern Lake Ontario*

Principal Investigator: R.B. Moore - State University of New York at Oswego

No report.

34. *Internal Waves - Transects Program - Interpretation of Whole-Basin Oscillations*

Principal Investigator: C.H. Mortimer - University of Wisconsin, Milwaukee

As reported in IFYGL Bulletin No. 9, the depth distribution of temperature has been plotted from undulator tapes and bathythermograph slides for 120 transects covering two sections of Lake Ontario: Braddock Point to Presqu'ile, and Oswego to Prince Edward Island. Through visits by F.M. Boyce and T.J. Simmons to our offices and my own visit to CCIW, a start has been made to correlate our findings with those from the Olcott-to-Oshawa section on cruises manned by the Canadian team on the R/V *Limnos*. Joint analysis is in progress, with joint interpretation as the objective. A paper on "Internal Waves" is being prepared, in collaboration with F.M. Boyce, for presentation at the AGU/AMS meeting in April 1974.

35. Pontoporeia affinis *and Other Benthos in Lake Ontario*

Principal Investigator: S.C. Mosley - University of Michigan

Sample Catalog:

Locations, depths, dates, and status of analysis of samples collected with the IFYGL epibenthic sled are given in table 1. For comparison, the Ponar grabsampler and zooplankton net samples are cataloged in table 2. To date, the sled, net, and grab samples indicated as having been analyzed have

been picked for macro-Crustacea only. Other benthic organisms in the samples have been preserved, but not sorted or counted. The *Pontoporeia affinis* have been sorted with respect to size and sex classes; *Gammarus* and Isopoda have been recorded simply as total number per sample; and *Mysis relicta* have been counted for totals and sent to J. Reynolds, University of Missouri, for further analysis. Other taxa in zooplankton were discarded.

Expected Output:

By March 15, 1974, publications should result on quality-control analysis of the Folsom plankton sample splitter used for reducing sled sample sizes for analysis, and on the structure and function of the IFYGL epibenthic sled. A manuscript covering the seasonal and regional *Pontoporeia affinis* information from sled tows will be completed for the 17 IAGLR Seventeenth Annual Conference in August 1974. Before March 1, 1974, contact will be reopened with the Great Lakes Fisheries Laboratory on joint publications, including the conference paper mentioned above, to compare fisheries data and fish diet information with *Pontoporeia affinis* data.

New Information:

Preliminary analysis of samples indicates that only very young and sexually mature *Pontoporeia affinis* are near the sediment-water interface, where they can be collected by the sled, until November, when all size classes become catchable.

Judging from the sled samples that could be obtained, synchrony and timing of reproduction of *Pontoporeia affinis* appear to be similar throughout the lake. Highly seasonal reproduction extends to about 40 m, below which reproduction is more or less continuous. This is similar to reports for this species from the Baltic Sea and Lake Michigan.

The predominance of *Gammarus* over *Pontoporeia affinis* in the southeastern and eastern sections of the lake is surprising in that it extends to depths of at least 40 m near Oswego. *Gammarus* is rare in fine-grained sediments elsewhere in the lake. Isopods are rare, but extend to depths below 70 m in the southeastern corner of the lake. Abundant isopods were found only at stations in the eastern end of the lake.

The transect off Olcott, N.Y., was very poor in all taxa of macrocrustaceans except *Mysis relicta*.

In spring, it is common to find large quantities of dead, post-reproductive females lying on the sediment surface to water depths as great as 75 m. This is interpreted as a natural phenomenon, not a result of pollution.

Table 1.--Sled samples collected from Lake Ontario, 1972-73

Ship	Transect	Station No.	Latitude N.	Longitude W.	Depth (m)	Julian Date 1972 (1973)
Kaho	Olcott, N.Y.	10	43°21.2'	78°44.4'	18.6	155,235
"	"	20	43°21.9'	78°44.5'	37.2	155,235
"	"	25	43°22.2'	78°44.4'	46.4	155,235*
"	"	30	43°22.4'	78°44.6'	55.7	155,235
"	"	40	43°22.9'	78°44.8'	74.3	155,235*
Kaho	Rochester, N.Y.	10	43°17.6'	77°35.8'	18.6	131,148,225,268*
"	"	20	43°19.2'	77°34.6'	37.2	131,148,225,268*
"	"	25	43°19.9'	77°34.5'	46.4	131,148,225,268*
"	"	30	43°20.7'	77°34.2'	55.7	131,148,225,268*
"	"	40	43°21.7'	77°34.2'	74.3	131,148,225,268*
Kaho	Nine-Mile Point, N.Y.	5	43°31.7'	76°23.1'	9.3	133,146,211,229, 270
"	"	10	43°31.8'	76°23.5'	18.6	" " " " "
Advance II	"	"	"	"	"	315
Limnos	"	"	"	"	"	(017)
Kaho	"	20	43°32.7'	76°24.0'	37.2	133,146,211,229, 270
Advance II	"	"	"	"	"	315
Limnos	"	"	"	"	"	(017)
Kaho	"	30	43°33.5'	76°24.4'	55.7	133,146,211,229, 270
Advance II	"	"	"	"	"	315
Limnos	"	"	"	"	"	(017)
Kaho	"	40	43°35.0'	76°25.0'	74.3	133,146,211,229, 270

Table 1.--Sled samples collected from Lake Ontario, 1972-73 (Continued)

Ship	Transect	Station No.	Latitude N.	Longitude W.	Depth (m)	Julian Date 1972 (1973)
Kaho	Galloo-Stoney Island, N.Y.	15	43°55.3'	76°11.4'	27.9	230
"	"	10	43°54.1'	76°15.9'	18.6	230
"	"	13	43°56.9'	76°19.5'	24.1	230
"	"	18	43°58.3'	76°26.7'	33.4	230
Kaho	Prince Edward Pt. Ontario	15	43°50.0'	77°03.5'	27.9	136,231
"	"	20	43°49.6'	77°01.7'	37.2	136,154,231*
Limnos	"	"	"	"	"	(018)*
Kaho	"	25	43°48.8'	77°03.8'	46.4	136,231*
"	"	30	43°47.8'	77°03.4'	55.7	136,154,231*
Limnos		"	"	"	"	(018)
Kaho	"	40	43°46.0'	77°02.5'	74.3	136,154,231*
Kaho	Cobourg, Ontario	20	43°54.7'	78°09.9'	37.2	149,234
Advance II	"	"	"	"	"	314
Limnos	"	"	"	"	"	(016)
Kaho	"	25	43°52.8'	78°11.8'	46.4	149,234
Advance II	"	"	"	"	"	314
Kaho	"	30	43°52.0'	78°10.1	55.7	149,234
Advance II	"	"	"	"	"	314
"	"	40	43°50.4'	78°13.8'	74.3	314
Kaho	Port Credit, Ontario	20	43°31.8'	79°31.3'	37.2	124

Table 1.--Sled samples collected from Lake Ontario, 1972-73 (Continued)

Ship	Transect	Station No.	Latitude N.	Longitude W.	Depth (m)	Julian Date 1972 (1973)
Kaho	Hamilton, Ontario	5	43°18.1'	79°46.8'	9.3	157,223,265
"	"	10	43°18.3'	79°45.0'	18.6	" " "
Limnos	"	"	"	"	"	(018)*
Kaho	"	20	43°19.1'	79°42.4'	37.2	157,223,265
Limnos	"	"	"	"	"	(018)*
Kaho	"	30	43°19.8'	79°40.2'	55.7	157,223,265
Limnos	"	"	"	"	"	(018)*
Kaho	"	40	43°20.8'	79°20.8'	74.3	157,223,265

*Not analyzed.

*Table 2.--Ponar grabsampler and zooplankton net samples collected from Lake Ontario, 1972**

Transect	Station	Device	Julian Date 1972	No. of samples	Remarks
Nine-Mile Point, N.Y.	5	Ponar	133	5	Analyzed
"	10	"	"	5	"
"	20	"	"	5	"
"	30	"	"	5	"
"	40	"	"	5	"
"	10	"	315(day)	3	Not analyzed
"	20	Net	314(night)	4	Analyzed; two full tows; two epilimnetic tows
"	20	Ponar	314(night)	3	Not analyzed
"	20	Net	315(day)	4	Analyzed; two full tows; two epilimnetic tows
"	20	Ponar	315(day)	3	Not analyzed
"	30	"	315(day)	3	Not analyzed
Cobourg, Ontario	20	Ponar	314(day)	3	Not analyzed
"	25	Net	314(night)	3	Analyzed full tows
"	25	Ponar	314(night)	3	1 analyzed
"	25	Net	314(day)	3	Analyzed full tows
"	25	Ponar	314(day)	3	Not analyzed
"	30	Ponar	314(day)	3	Analyzed
"	40	Ponar	314(day)	3	Not analyzed

*See table 1 for station geographic coordinates, depths, and ship platforms.

Quality Control and Sampling Error:

Replicate samples with the IFYGL sled indicated that quantitative estimates of population abundance from sled tows were not feasible. The repeatability of size/sex class distribution in sled samples was very poor for samples totaling fewer than 200 individuals. Above this amount, replicate tows were homogeneous within random expectation for very small and sexually mature individuals, but often nonhomogeneous for intermediate classes. The sled sampled *Pontoporeia affinis* quite differently from the Ponar grab at depths of less than 55 m. Below 55 m, the sled dredged mud rather than skimming along the sediment surface, and sled and grabsampler data were therefore similar.

The subsampling device, or sample splitter, performed reliably and accurately in reducing sample sizes while retaining size-sex class distributions in the samples. An expression was derived to predict the precision of estimates of total sample sizes from subsamples obtained with the splitter.

36. *Pan Evaporation Project*

Principal Investigator: C.N. Hoffeditz - NWS/NOAA

Initial analysis of the radiation data indicates that data are missing for many days because of equipment failure. Voltage integrating recorders failed intermittently, and for some periods data cannot be recovered. In other respects, there seem to be no major problems. Consistency checks of the pan evaporation data from the three Canadian stations showed these data to be of good quality.

Analysis of the data from the United States stations is behind schedule because dewpoint and radiation data have not been received from the collocated Physical Data Collection System stations. When they become available, shallow-lake evaporation computations will be made. With receipt of the change in energy storage and advected energy data from the Energy Budget Group, corrections will be made to obtain Lake Ontario evaporation estimates.

37. *Simulation Studies and Other Analyses Associated With U.S. Water Movements Projects*

Principal Investigators: J.P. Pandolfo and C.A. Jacobs - CEM

Progress has been made on the three-dimensional model. The computer program for the free-surface model was modified for more rapid execution at lower cost. This was done by converting the FORTRAN program from the IBM 360/65 to the CDC 7600. The logical flow of the program was modified to decrease running time by about one-third. Data input for the free-surface version of the model was made compatible with that required by the rigid-lid version, which will save much time in preparing input and reduce errors when data sets are to be run with the several versions of the three-dimensional model that are planned.

A preliminary, horizontal grid array of 108 stations (6 by 18) with a grid distance of 17.5 km has been chosen for the three-dimensional model to simulate the Lake Ontario region. The superposition of this grid on a map of Lake Ontario with the designation of the type of station for each grid point is shown in figure 4. (The types of stations, e.g., land, air/land interface, are defined in "A Description of a General Three-Dimensional Numerical Simulation Model of a Coupled Air-Water and/or Air-Land Boundary Layer," CEM Report No. 438, Vol. I, January 1973.) The grid allows for inflow and outflow at boundary stations.

The vertical grid, in meters, to be used in preliminary simulation is as follows:

1,200	0	- 35
900	0	- 40
650	- 1	- 45
450	- 5	- 50
300	-10	- 75
150	-15	-100
75	-20	-150
25	-25	-180
4	-30	-210

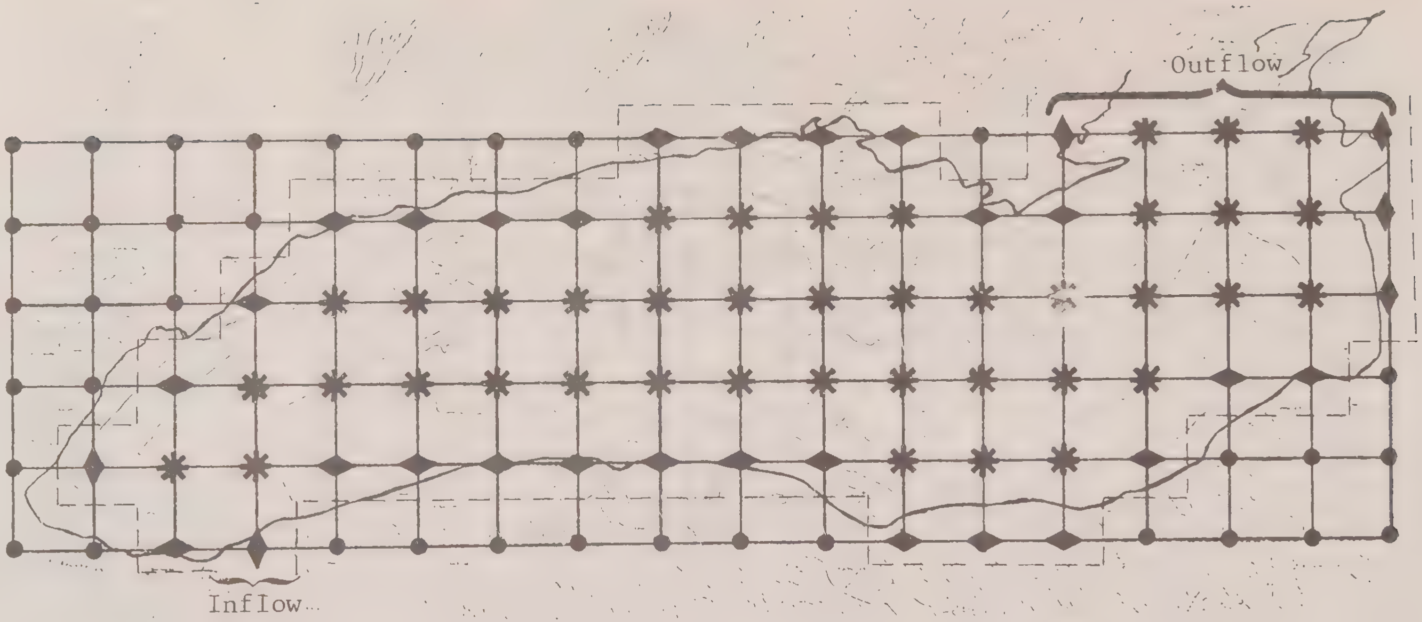
July climatology and results of the one-dimensional simulation of a July cold front passage have been used to prepare the first input data set for the three-dimensional grid. Future plans are to run several three-dimensional simulations with different, free-surface and filtered, versions of the model for selected IFYGL periods. It is hoped that some of the periods chosen will be used by other modelers. J. Simons of CCIW has already prepared a data set for model input and verification for several days, centered on August 9, 1972.

38. *Structure of Turbulence*

Principal Investigator: H.A. Panofsky - Pennsylvania State University

A paper dealing with coherence and phase delay has been written for submission to the Swinbank Memorial Volume of Boundary Layer Meteorology. One thesis on the subject is in progress.

Vertical phase delay has been shown to be proportional to vertical wind shear. Space-time correlations have been used to analyze quasi-Lagrangian statistics. A theory has been developed to relate the Lagrangian-Eulerian ratio β to the coherence decay constant a. Dissipation and stress have been estimated for a windy period. Dissipation varies little with height compared with energy production, suggesting that energy is lost through transport at 2 m and gained at 7 m. Observations of coherence at Richland, Wash., suggests



Land Station (Air-Soil Interface)

East-West Coastal Station (Water flow only permitted in an east-west direction at these stations, air-water interface)

North-South Coastal Station (Water flow only permitted in a north-south direction at these stations, air-water interface)

Water Stations (No restriction on water flow, air-water interface)

– – – Location of Shoreline Associated With the Above Grid Array

Figure 4.--Model grid.

that the theory used so far is too simple. Possibly, a new factor is the ratio of separation to height, which decreases coherence. The results will be presented to the Melbourne Assembly of IAMAP in January 1974. Research on quasi-Lagrangian observations and theory will continue, along with studies of the turbulent energy budget.

39. *Airborne Snow Reconnaissance*

Principal Investigator: E.L. Peck - NWS/NOAA

The Airborne Snow Reconnaissance Interim Report # 5, "Water Equivalent of Snow Data from Airborne Gamma Radiation Surveys - International Field Year Great Lakes," was published on December 17, 1973, by EG&G, Inc. It contains aerial measurements of the water equivalent of snow cover for approximately 350 line miles that were surveyed in the Lake Ontario Basin during IFYGL. Measurements were made by three gamma radiation techniques: total gamma flux, and specific energy components for ^{208}Tl and ^{40}K. Ground-truth information collected for selected calibration flight lines compared favorably with the airborne measurements. Mile-by-mile water equivalent values are presented for all survey lines, based on the total or net count method.

40. *Optical Properties of Lake Ontario*

Principal Investigator: K.R. Piech - Calspan Corporation

During the quarter, an annual report was prepared, an updated program summary was presented at an Energy Balance Panel Review and Workshop, chlorophyll analyses were begun on data supplied by CCIW, and intersensor comparisons were continued.

Average chlorophyll values for the various cruises are given in table 3. The data used in obtaining these values are only from lake stations where optical measurements were made. Reasonable correlation seems to exist between these values and the optical data, both surface and aerial. We are currently attempting to obtain chlorophyll data for the August 21 cruise week. Reduced aerial data for the October 16 cruise week should be available by the end of the next reporting period; some delay was caused by difficulty in obtaining a fiber-optics probe of proper size for the densitometer.

Both aircraft and Skylab imagery over Lake Ontario for September 9 and 10, 1973, have been received. These data yield average reflectances of blue $\sim$2.9, green $\sim$2.1, and red $\sim$0.6, with corresponding blue/green and blue/red ratios of 1.4 and 4.8. Lake conditions on these dates appear to be similar to those for corresponding dates in 1972 (week of September 11, 1972), and table 3 suggests an average chlorophyll content of about 7 $\mu g/m^3$ for September 9, 1973. Firmer statements should be possible as the Skylab Program progresses.

Plans for the next quarter include completion of both the intersensor comparisons and chlorophyll analyses for the lake stations.

Table 3.--Lakewide average of optical parameters

Parameter		Cruise week May 1	May 25	June 12	July 10	Aug. 21	Sept. 11	Oct. 16	Oct. 29	Nov. 27
Secchi disk transparency (m)[1]		4.2	5.8	5.7	4.0	3.0	3.8	5.4	6.4	--
Attenuation coefficient (m^{-1})		1.32	1.56	1.51	1.90	1.93	1.45	1.28	0.78	1.15
1 percent relative irradiance level (m)	Red	--	3.3	4.9	4.4	3.9	3.8	5.1	5.3	--
	Green	--	7.5	8.8	7.2	6.2	7.0	10.4	10.4	--
	Blue	--	5.5	6.4	4.3	3.8	4.3	6.3	6.7	--
Percent reflectance	Red	--	--	0.9*	2.7	1.7	1.3	*	--	--
	Green	--	--	2.0*	3.5	3.0	1.8	*	--	--
	Blue	--	--	3.0*	4.3	3.1	2.2	*	--	--
Reflectance ratio[2]	Blue/Green	--	--	1.5*	1.3	1.1	1.3	*	--	--
	Blue/Red	--	--	3.6*	1.7	2.0	1.8	*	--	--
Chlorophyll[1,3] ($\mu g/m^3$)		--	3.8	6.9	7.4	--	7.2	2.9	--	1.4

[1]Values from stations where other optical measurements were made.

[2]Average of reflectance ratios measured at each station.

[3]Average of samples taken at 1- and 5-m depths.

*Additional data to become available.

41. *Storage Term - Energy Balance Program*

Principal Investigator: A.P. Pinsak - LSC/NOAA

Studies have been made of the variation in heat storage in the lake during some of the IFYGL cruises.

42. *Sensible and Latent Heat Flux*

Principal Investigator: A.P. Pinsak - LSC/NOAA

No report.

43. *Thermal Characteristics of Lake Ontario and Advection Within the Lake*

Principal Investigator: A.P. Pinsak - LSC/NOAA

No report.

44. *Oswego Harbor Studies*

Principal Investigator: G.L. Bell - LSC/NOAA

A computer listing of the coliform data from the 1971 and 1972 studies of Oswego Harbor and vicinity was furnished to Richard Moore, State University College at Oswego, N.Y.

45. *Mapping of Standing Water and Terrain Conditions With Remote Sensor Data*

Principal Investigator: F.C. Polcyn - University of Michigan

No report.

46. *Remote Sensing Program for the Determination of* Cladophora *Distribution*

Principal Investigators: F.C. Polcyn and C.T. Wezernak - University of Michigan

No report.

47. *Remote Sensing Study of Suspended Inputs Into Lake Ontario*

Principal Investigators: F.C. Polcyn and C.T. Wezernak - University of Michigan

No report.

48. *Island-Land Precipitation Data Analysis*

Principal Investigator: F.H. Quinn - LSC/NOAA

No report.

49. *Lake Circulation, Including Internal Waves and Storm Surges*

Principal Investigator: D.B. Rao - University of Wisconsin, Milwaukee

No report.

50. *Atmospheric Water Balance*

Principal Investigator: E.M. Rasmusson - CEDDA/NOAA

Rawinsonde data collected at all six stations during two 6-day periods, October 6 to 11 and October 30 to November 4, have been processed. These data are being examined in order to identify and correct remaining weaknesses in the error-detection portions of the processing software.

51. *Evaporation Synthesis*

Principal Investigator: F.H. Quinn[5] - LSC/NOAA

No report.

52. *Groundwater Flux and Storage*

Principal Investigator: E.C. Rhodehamel - U.S. Geological Survey

No report.

53. *Spring Algal Blooms*

Principal Investigator: A. Robertson - IFYGL Project Office/NOAA

Analysis awaits availability of data.

54. *Ice Studies for Storage Term - Energy Balance*

Principal Investigator: F.H. Quinn - LSC/NOAA

Completion of a data report is approximately 6 weeks behind schedule. No further studies are planned.

55. *Lagrangian Current Observations*

Principal Investigator: J.H. Saylor - LSC/NOAA

No report.

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[5] F.H. Quinn has replaced E.M. Rasmusson as Principal Investigator on this task.

56. *Circulation of Lake Ontario*

Principal Investigator: J.H. Saylor - LSC/NOAA

No report.

57. *Phytoplankton Nutrient Bioassays in the Great Lakes*

Principal Investigator: C. Schelske - University of Michigan

Task not activated.

58. *Runoff Term of Terrestrial Water Budget*

Principal Investigator: G.K. Schultz - U.S. Geological Survey

Work on this task is complete.

59. *Coastal Chain Program*

Principal Investigator: J.T. Scott - State University of New York at Albany

Work is progressing on Data Report No. 2, an analysis of transport processes. Some basic work has been done on Report No. 3, covering coastal transport processes, but ship, tower, and buoy data have to be studied before this work can be carried further. For Report No. 4, examination of coherence between coastal chains for selected events has begun. The Rochester embayment study is nearly finished, and it will be published as soon as pertinent tower and buoy data are received. A coherence study of two events, with emphasis on Kelvin waves, has been completed in collaboration with G.T. Csanady.

60. *Analysis of Phytoplankton Composition and Abundance*

Principal Investigator: E.F. Stoermer - University of Michigan

No report.

61. *Clouds, Ice, and Surface Temperature*

Principal Investigator: A.E. Strong - NESS/NOAA

No report.

62. *Analysis and Model of the Impact of Discharges From the Niagara and Genesee Rivers on Nearshore Biology and Chemistry*

Principal Investigator: R.A. Sweeney - State University of New York at Buffalo

No report.

63. *NCAR/DRI - Buffalo Program*

Principal Investigator: J.W. Telford - Desert Research Institute, University of Nevada

The main activity during the quarter consisted of reducing and analyzing the meteorological data gathered by the "Buffalo Research System" over Lake Ontario in May, August, October, and November 1972.

On the Buffalo aircraft used in gathering these data, an inertial platform and a navigational computer provide accurate measurements of aircraft acceleration, velocity, position, and attitude angles. Various devices and air-sensing probes located on a nose boom in front of the airplane measure air velocity, angles of attack, sideslip, temperature, pressure, and dewpoint These measurements are displayed in real time for scientific and pilot flight planning. They are also recorded on magnetic tape at a rate of approximately six times per second for postflight analysis.

Twenty flights were made, each flight producing almost a full magnetic tape of data. In order to process this vast amount of interrelated navigational and meteorological data, reduction has been divided into five major phases:

(1) A "first-look" processing of the original aircraft tapes, whereby the raw data are unpacked, reformated, and rescaled to convenient units. The result is an intermediate data tape more suitable for subsequent analysis and calculations.

(2) Use of the condensed tape for calculations of wind, temperature, and other meteorological variables, as well as adjustments and calibrations of the sensors. Recordings of similar real-time calculations on the computer aboard the aircraft provides a good accuracy check. The output of this phase in processing contains measured and calculated values (both real time and postflight) of navigational and meteorological variables, in most cases at a rate of approximately six times per second. The variables include airplane velocity and attitude angles; velocity and angles of incidence of the airstream with respect to the aircraft frame; time; position; three wind components; temperature; pressure; and humidity. Other parameters that can be derived, such as virtual temperature and mixing ratio, may also be included in the output.

(3) Production, by means of several plotting programs developed in the course of the analysis, of graphic data displays for overall visual analysis and interpretation.

(4) Detailed analysis from a meteorological standpoint of the data reduced in phases (1), (2), and (3). Several theoretical and numerical procedures will be used for this analysis, and the average wind gradient, convergence, shear stress, fluxes of heat and moisture, and other parameters will then be calculated.

These calculations, and the graphic displays, will serve as the foundation for an understanding and interpretation of many novel features revealed by the measurements. They will also help us analyze the structure of the wind, study airmass modifications, and interface our findings with those of other investigators. The data set will not only provide the practical meteorologist with precisely located, simultaneous measurements of various parameters in the Lake Ontario area, but will, it is hoped, also give the theoretician an unprecedented set of observations in the real atmosphere, based on which new, realistic models and theories can be developed.

The following tasks have been completed:

(a) Of the 21 flight tapes, 12 have been processed through phase (1). Temporary delay has been caused by the necessity to modify our main processing program to make it compatible with a new computer that has been acquired.

(b) Two tapes for flights on November 5 and 8, 1972, have been processed through phases (2) and (3). All quantities, except vertical wind velocity and humidity, have been evaluated. Horizontal wind vectors and temperature profiles have been plotted. Initial results for the flight on November 5 indicate a rather strong vertical shear of the horizontal wind and a wave disturbance with a wavelength of approximately 16 km on a northwest-to-southeast flight leg over the lake. Further analysis of these features is in progress.

(c) Several plotting programs have been completed. Aircraft ground track and altitude, horizontal wind components, and temperature profiles can now be plotted on a graph showing the geographic boundaries of the lake.

(d) For cases when the aircraft was flown in closed-square patterns aligned with the wind, and at various constant altitudes, the horizontal divergence of the wind has been calculated by an integral method. The average gradient of the horizontal wind component has also been calculated by means of a least-squares fit to the data, which will permit calculation of vorticity and horizontal convergence of the wind for comparison with the integral technique.

Plans are to continue analysis, and to process the vertical wind velocity and moisture measurements. Shear stress and fluxes of heat and moisture for the November 5 flight will then be calculated. Attempts are being made to improve methods for displaying the three-dimensional structure of the wind, and efforts will begin to develop stereographic and stereoscopic wind plots on the computer.

64. *Mathematical Modeling of Eutrophication of Large Lakes*

Principal Investigator: R.V. Thomann - Manhattan College

Preliminary runs were continued for the 7-vertical-layer, 14-system LAKE 2 model. In addition to biological and chemical systems, the model

includes a temperature system, driven by a surface-layer boundary condition, that forces the stratification and mixing phenomena of the lake. Computed results of this system compare well with observed temperatures. A dispersion regime has been established and the temperature verified. Efforts are now being focused on verification of the biochemical systems.

The LAKE 2 biochemical systems include phytoplankton and zooplankton biomass, organic nitrogen, ammonia, nitrite, nitrate, phosphate, organic phosphorous, total inorganic carbon, alkalinity, organic carbon, and dissolved oxygen. These systems interact through the phytoplankton and zooplankton kinetics, which depend on growth rates and Michaelis constants for nitrogen, phosphorous, carbon, and chlorophyll, nitrogen hydrolysis rates, phosphorous conversion rates, oxygen evolution from CO_2 and NO_3 assimilation, and denitrification. The complex interactions are handled through continuous updating of the chemical systems in line with biological uptake and production.

Structuring of the 67-segment spatial (horizontal and vertical) LAKE 3 model was completed. Tributary flow and waste loadings and boundary concentrations from the available data have been added to the segmentation scheme.

Plans for the next quarter are to continue biochemical verifications runs for LAKE 2, and to begin preliminary runs on the LAKE 3 model to verify transport schemes. Temperature will be used as the verification criterion.

65. Cladophora *Nutrient Bioassay*

Principal Investigator: G.F. Lee[6] - University of Texas at Dallas

Inactive.

66. *Sediment Oxygen Demand*

Principal Investigator: N.A. Thomas - EPA

Data analysis has been completed, and calculations of all sediment oxygen demand rates have been placed on a contour map. A report describing methodology, observations, and areas of interest has been prepared. Rates for various sections of the lake can be obtained from the author.

67. *Main Lake Macrobenthos*

Principal Investigator: N.A. Thomas - EPA

All identifications have been completed. The results are being tabulated and should be available by the end of March. A report is being prepared on the methodology for interpretation of the data.

[6] The Principal Investigator is now affiliated with the University of Texas at Dallas.

70. *Evaluation of ERTS Data for Certain Hydrological Uses*

Principal Investigators: D.R. Wiesnet and D.F. McGinnis - NESS/NOAA

NOAA-2 very high resolution radiometer (VHRR) images were used to prepare snow-cover maps for the Lake Ontario basin on two cloudfree days: February 13 and March 8, 1973 (figs. 5 and 6). In each case, the image (visible band 0.6 to 0.7 μm) was "rectified" optically by means of a Zoom Transfer Scope to fit a basin map. Areas of open water were also recorded. Ice was visible in Prince Edward Bay and Wellington Bay. Forested areas were delineated in the Adirondack Mountains and Tug Hill Plateau in the United States and in southern Ontario. The only snowfree area was mapped on the north shore of Lake Ontario between Toronto and Cobourg. Snow cover was 99 percent.

On March 8 there was only 32 percent of snow in the basin according to the satellite measurement. Snow-depth data for selected meteorological stations have been ordered. VHRR images are currently screened daily for suitable cloudfree views of the basin. ERTS-1 images do not lend themselves to synoptic snow-cover mapping of the entire Lake Ontario basin. In the 1972-73 winter season it was not possible to get one cloudfree sequence of the entire basin. ERTS-1 is superb for mapping smaller subbasins that can be imaged on one or two frames, say 250 km^2 to 30,000 km^2, but larger basins are usually not cloudfree 2 or 3 days in a row. For large basins NOAA-2 VHRR should be used for snow-cover mapping as the entire basin can be viewed on one pass if there are no clouds.

Work on soil moisture has been suspended until a color densitometer, which has now been ordered, arrives. Delivery is expected in January.

Two papers were presented during the quarter:

Wiesnet, D.R., "The Role of Satellites in Snow and Ice Measurement," Proceedings of IHD Symposium on Advanced Concepts for Snow and Ice Management, Monterey, Calif., December 9-13, 1973 (in press).

Wiesnet, D.R., and D.F. McGinnis, "Snow-Extent Mapping and Lake Ice Studies Using ERTS-1 Together With NOAA-2 VHRR, "Proceedings of the Third ERTS Progress Symposium, Washington, D.C., December 17-20, 1973 (in press).

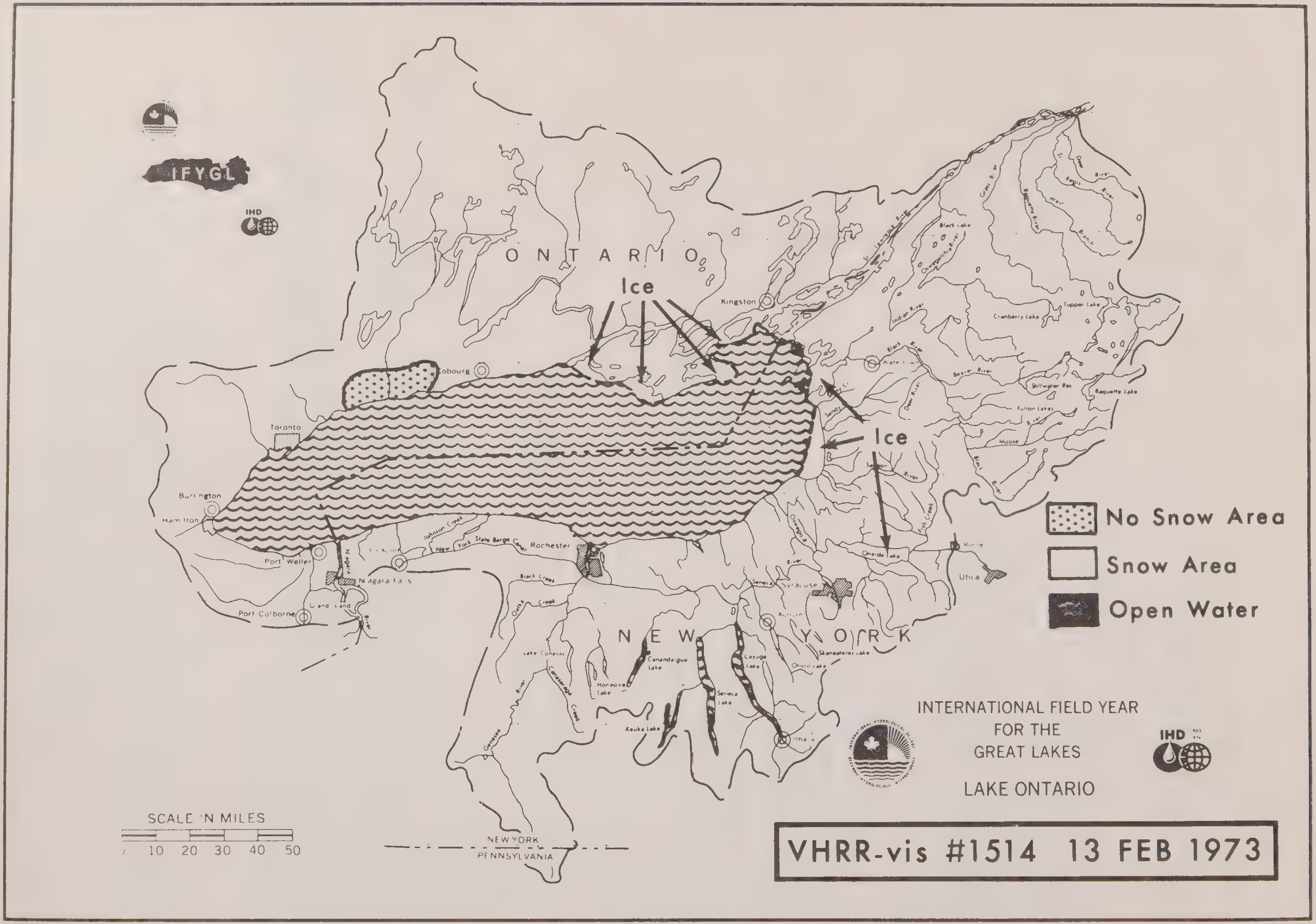

Figure 5.--Snow and ice extent on February 13, 1973, determined from NOAA-2 VHRR-VIS data.

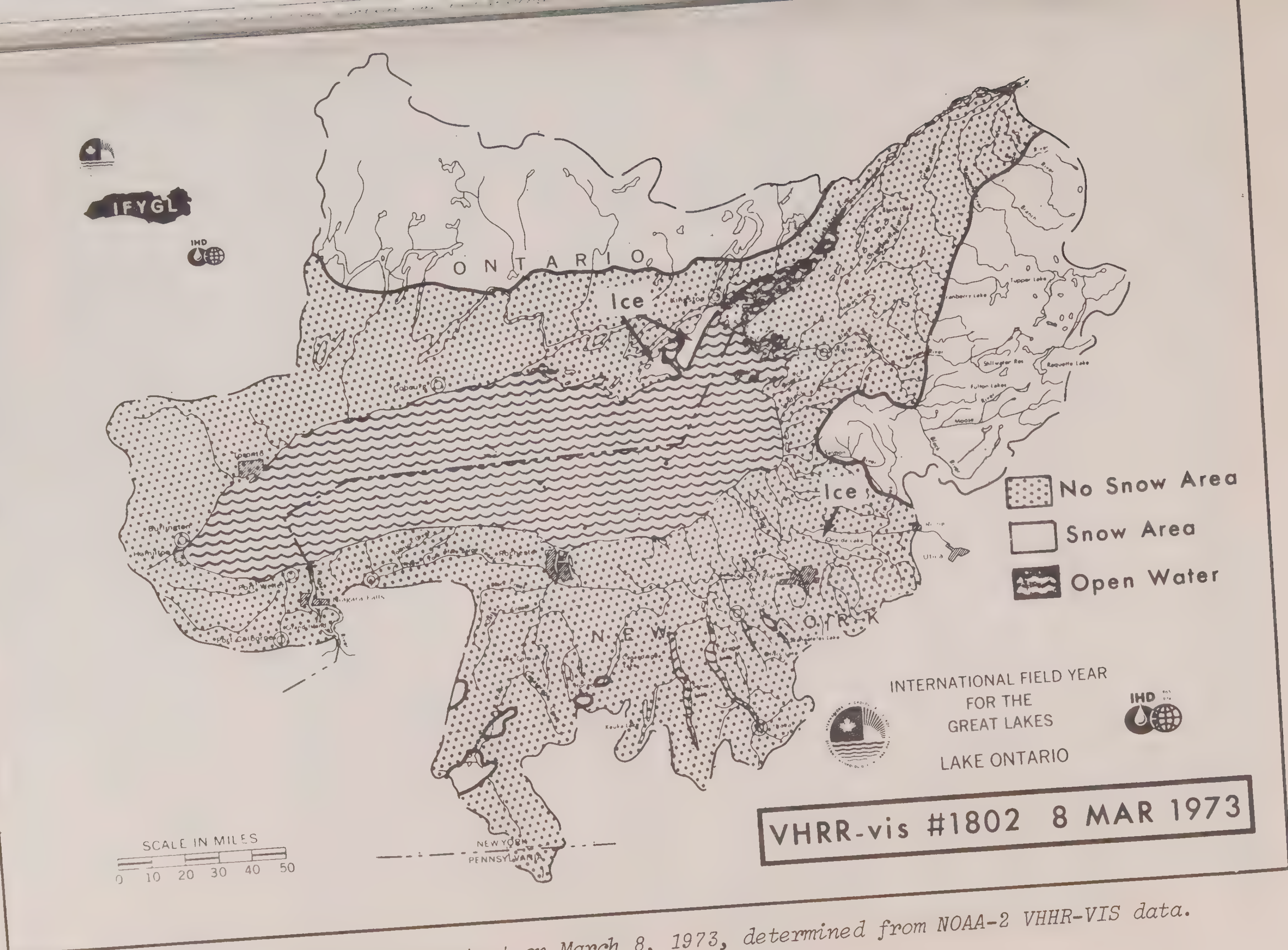

Figure 6.--Snow and ice extent on March 8, 1973, determined from NOAA-2 VHHR-VIS data.

71. *Distribution, Abundance, and Composition of Invertebrate Fish Forage Mechanisms in Lake Ontario*

Principal Investigator: J.H. Kutkuhn[7] - Great Lakes Fisheries Laborato

During the last two quarters, we examined the stomachs of 784 smelt and 490 alewives, as well as samples of crustacean zooplankton from 102 vertical tows. The data are being analyzed, and a manuscript is in preparation.

Small fish and benthic invertebrates, such as *Pontoporeia affinis*, *Mysi relicta*, and *Gammarus* sp., made up the bulk of the material ingested by smel Zooplankton (largely *Cyclops bicuspidatus thomasi* by number and *Limnocalanus macrurus* by weight), insects (midges), mollusks, *Asellus* (Isopoda), and ostr cods entered the smelt diet in lesser amounts.

The food of alewives consisted almost entirely of zooplankton, *Cyclops bicuspidatus thomasi* being the most important item in number and weight. Only occasionally were cladocerans like *Daphnia* spp. (mostly *D. retrocurva*) and eubosminids (mostly *Bosmina longirostris*) well represented in alewife stomachs. Although larger crustaceans, insects, and mollusks were never numerically abundant, they contributed about 20 percent by weight to the tot alewife diet.

We did not note any tendency by alewives toward size-selective predatio on large zooplankters, a phenomenon that has been frequently suggested as a cause of documented changes in the composition of zooplankton populations from large- to small-bodied species.

72. *Coastal Circulation in the Great Lakes*

Principal Investigator: G.T. Csanady - Woods Hole Oceanographic Institution

Most of the effort during this quarter was expended on an analysis of several storm episodes in the spring and summer of 1972. With data being available from most of the other investigators, more conclusive results coul be reached than were possible earlier. Particularly useful were data on the wind stress, calculated from surface winds by F.C. Elder, fixed current mete observations processed by E.B. Bennett, and the south-shore coastal-chain data furnished by J.T. Scott.

Analysis of two storms during the spring alert period is described in a revised version of W.H.O.I. Contribution No. 3053. Analysis of two storms during the summer alert period is covered in a paper prepared jointly with J.T. Scott. This paper, now almost complete, also contains a theoretical discussion of internal Kelvin-wave generation by winds in a fairly long rectangular basin and represents an extension of earlier theoretical work on a

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[7] J.H. Kutkuhn has replaced J.F. Carr as the Principal Investigator on this task.

rcular Model Great Lake. Some remarkable instances of coastal jet reversal e documented in this paper and related quantitatively to the linear theo- tical model. Both manuscripts will be transmitted soon in final form to e IFYGL Project Office.

. *Lake Water Characteristics*

Principal Investigator: A.P. Pinsak - LSC/NOAA

Further coordination with Task 7 is required before work can continue.

. *Snow Observation Network*

Principal Investigator: R.B. Sykes - State University of New York at Oswego

The purpose of this task is to supplement last year's snowfall program rough additional study of snowfall conditions, including some photography snowflakes and ice crystals and some replication of both crystals and akes. This study covers two of the five districts used during IFYGL: the mden and Central Square school districts. These were chosen partly because the effectiveness of the local monitor in charge during the Field Year, and rtly because Camden is located just east of Central Square.

Eight of the 13 gages used last year were installed again, 7 of them at e same sites. This was done in late October and early November 1973.

Revised instructions and appropriate format for the observations were stributed before Christmas. They were used experimentally in the Central uare district, and only minor points had to be cleared up. Consultations re carried out with James Wilson, and contact was established and main- ined with the districts. Student assistants provided some instruction cally and serviced established precipitation gages. Experienced help was ailable from the previous season for installation, maintenance, and serv- ing of the gage sites. Two mobile telephones were installed to allow ntact as necessary.

Approximately 30 locations were chosen for surface weather observations. general, these included routine morning and evening observations, as well additional observations under snow conditions. Snow conditions have con- nued to be poor over the two school districts, although conditions around wego have been better than last year.

Preliminary results of replication and photography are favorable.

. *Lake Circulation Model*

Principal Investigator: J.R. Bennett - IFYGL Project Office/NOAA

As a first step in investigating the cyclonic circulation of large lakes, problem was studied with a simple numerical model. The results of this

study will be presented at the AGU/AMS meeting in April. The following abstract has been submitted:

> "On the Cyclonic Circulation of Large Lakes. Emery and Csanady (1973) have shown that almost all lakes and large seas in the northern hemisphere have a counter-clockwise surface circulation. Their explanation is that the surface water is advected to the right of the prevailing wind and that over this warm water there is an increased drag of the air on the water; the resulting cyclonic wind stress drives the cyclonic surface currents. Here it is shown that the cyclonic circulation can be explained solely by the action of a constant prevailing wind stress acting on a stratified lake and that the air-sea interaction part of their theory is not necessary. This is done by driving a two-dimensional 'cross section numerical model' with a uniform wind stress. From a motionless initial state with no horizontal temperature gradient the surface water is advected to the right of the wind. Since that side is then more stratified than the upwelling shore the effect of further wind forcing is confined to the upper layer, giving a stronger current in the direction of the wind. The two theories are now being tested against data collected during the International Field Year for the Great Lakes."

An objective analysis scheme developed by John Jalickee, CEDDA, is bein used to test these theories against Field Year data.

76. *Lake Ontario Invertebrate Faunal List*

Principal Investigator: A. Robertson - IFYGL Project Office/NOAA

Work is progressing satisfactorily on estimating, where feasible, the distribution and abundance of the various forms in Lake Ontario.

77. *Natural Distribution and Variability of Physical Lake Properties*

Principal Investigators: E. Aubert, J. Harrison, and R. Pickett - IFYGL Project Office/NOAA

The data base prepared on a random access disk pack has been expanded and now includes Canadian current buoy measurements through mid-November 1972, Canadian meteorological buoy measurements through mid-September 1972, United States Physical Data Collection System measurements for July 1972, a hourly averages for portions of the above data sets.

From the July 1972 edited hourly averages, the following have been generated:

Monthly mean temperature charts for 0, -10, -15, -30, and -50 m.
Monthly prevailing surface winds.
Monthly prevailing and resultant currents for all current-meter levels.
Chart of monthly mean thermocline position.
Spectra at all levels for U.S. stations.
Filtered plots of thermocline inertial oscillations for U.S. stations.

78. *Carbon Cycle Model*

Principal Investigators: A. Robertson and B. Eadie - IFYGL Project Office/NOAA

A preliminary carbon budget for Lake Ontario durig IFYGL has been calculated. Refinement of these estimates is proceeding slowly because of difficulties in obtaining further data.

A first-generation model of vertical fluctuations of various parameters at a typical deepwater station in Lake Ontario has been developed. This model predicts variations in pH, alkalinity, phytoplankton, zooplankton (three types), temperature, the components of the inorganic carbon system, and phosphate. The model is being adapted to predict these parameters for a cross section of the lake. Physical driving forces for the two-dimensional model are being generated from a model developed by J. Bennett under Task 75.

Project Areas

Biology and *Chemistry - N.A. Thomas,* U.S. Panel Cochairman

Investigators are working on various sections of a State-of-IFYGL Report for biology and chemistry. This report will be integrated with Canadian input and should be available by spring 1974. It summarizes what has been done, what will be the output in terms of authorship and content, and what the data show so far.

Boundary Layer - J.Z. Holland, U.S. Panel Cochairman

During this period, the panel did not meet. The individual panel members continued their respective projects and interchange of data.

Terrestrial Water Balance - B.G. DeCooke, U.S. Panel Cochairman

A meeting of the U.S. Terrestrial Water Balance Work Group was held in Detroit on December 11 and 12, 1973, to discuss the progress of the assigned tasks, and to plan the work necessary to complete the tasks and prepare the final Panel report. Monthly data for the Field Year are now available for the following terms of the Water Budget equations:

Outflow from Lake Ontario.
Runoff into the lake from the U.S. land basin.
Precipitation on the U.S. land area.
Ground water contribution to the lake.

The data collected by other investigators are expected to be reduced and available before the end of Fiscal Year 1975. The delays in reducing data are mainly caused by manpower shortages, which should be remedied during the next 6 months.

The work group discussed at some length a rough draft of an outline for the final report. A draft of the outline, revised to include the items discussed at the meeting, will be distributed to all members of the Panel in Canada and the United States for review and comments. Plans are to write the final report in Fiscal Year 1975.

DATA MANAGEMENT

Rawinsonde Processing

Rawinsonde data collected by all six stations from October 6 to 11 and October 30 to November 4, 1972, have been processed. This includes manual corrections and conversion to scientific units. All data will be available in archive format in June 1974. They will be stored in 5-s, 10-mb, and 50-mb data sets.

Ship System

Processing is on schedule. One-second surface data have been computed for all cruises. All navigation data from dead-reckoning abstracts and on-station (EBT) data have been completed. The XBT data are being processed by the National Oceanographic Data Center (NODC) and will be completed in May. Because of manpower limitations, CEDDA can at present service only requests for a very small amount of data. By December the entire data set will be available in archive format.

Physical Data Collection System (PDCS)

Provisional PDCS data for May, July, and October 1972 are available on BCD and CDC 6600 binary magnetic tapes and microfilm time-series displays, as well as microfilm displays of the individual 6-min observations. These sets contain merged data from all PDCS sources, with all calibrations applied. Since no editing has been done, gross errors may be present.

STATUS OF THE CHEMICAL INTERCOMPARISON PROGRAMS CONDUCTED DURING IFYGL

A. Robertson

Three intercomparisons of chemical analyses were conducted during IFYGL. These studies covered total phosphorus, orthophosphate, total Kjeldahl nitrogen, ammonia, nitrate, pH, total organic carbon, sulfate, alkalinity, calcium, magnesium, manganese, lead, zinc, cadmium, copper, iron, potassium, and sodium.

In the first study, samples of known concentrations for the various parameters were sent for analysis to a number of laboratories. Statistical analysis of the results indicates systematic differences among the laboratories for most of the parameters. Data from this study also show that the random error component of the variance increased when the analyses were carried out at different times or, in other words, that the systematic errors in the various laboratories were not constant with time.

In the second study, samples were obtained at four depths at each of two stations, and each sample was split into four parts. One part was analyzed immediately aboard ship. The other three subsamples were frozen and sent to CCIW, OWRC (now Ministry of the Environment), and the EPA laboratory in Rochester, and the same analyses were conducted as aboard the ship. This procedure was carried out five different times. Statistically significant differences were found among the results from the three laboratories for many of the parameters. Analyses by CCIW of the frozen and unfrozen subsamples showed that freezing had a significant effect on many of the results.

In the third study, the IFYGL research vessels *Researcher* and the *Martin Karlsen* were brought together on two different dates, and similar sampling programs were carried out on both ships. Series of replicate samples were obtained by the two vessels, and one of the replicates was analyzed by each of three laboratories. The analyses indicate that differences in sampling methods used aboard the vessels probably had a relatively minor effect on the results obtained. However, substantial differences in the results from the different laboratories for a number of parameters were again found. Two similar intercomparisons programs were conducted on the *Researcher* and several smaller U.S. IFYGL vessels. The results have not yet been analyzed.

Preliminary reports have been prepared on the first and the third study described above. Copies can be obtained by writing to: Andrew Robertson, National Oceanic and Atmospheric Administration, EM7/IFYGL, NBOC-1, 6010 Executive Blvd., Rockville, Md. 20852. A summary report of the chemical intercomparisons is being prepared for presentation at the IAGLR conference in August 1974, and for publication in the proceedings from that conference.

OMPARISON OF JULY TEMPERATURE STATISTICS FROM ADJACENT BUOYS AT STATION 13

R.L. Pickett and F.P. Richards

Two intercomparisons of United States and Canadian sensors have been eported so far: a special test comparing buoy sensors (IFYGL Bulletin o. 3), and a similar test of shipboard sensors (Bulletin No. 4). In this ote, a comparison is made between temperatures recorded during July 1972 by djacent United States and Canadian buoys at station 13, at approximately 3°26'N. 78°44'W.

Monthly mean temperatures and associated standard deviations at the surace and -15 m for about 7,000 United States observations and about 4,000 anadian observations are given below. The same statistics are given for ourly averaged temperatures (about 700 observations).

	Surface		-15 m	
	United States	Canadian	United States	Canadian
ean of original data	19.4°C	19.2°C	12.0°C	11.6°C
andard deviation of original data	3.13	3.42	4.68	4.53
an of hourly verages	19.6	19.3	12.0	11.6
andard deviation f hourly averages	3.14	3.14	4.66	4.51

The United States temperatures tend to be higher and show slightly less atter at the surface and slightly more scatter at -15 m than the Canadian. IFYGL Bulletin No. 3, numerous causes were listed for the differences in e temperature systems, e.g., different sampling rates, response times, and orage systems. Most of these however, will not explain long-term statistil differences such as those shown above.

One explanation might be that the Canadian sensors were located about lf a meter deeper than the United States sensors. The mean vertical graent in July measured by the buoys was about -0.28°C/m at the surface and out -0.96 C/m at -15 m. This gradient would be sufficient to produce most the mean differences. Also, monthly standard deviations increase from the rface to the thermocline (-10 to -15 m), then decrease below. The Canadian nsors, being located at a slightly greater depth, would show slightly larger atter near the surface and slightly smaller below the thermocline.

In summary, the statistical differences may stem from sensor location, but these differences appear to be reasonably small.

U.S. PUBLICATIONS ON IFYGL

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ınsen, A.L., J.W. Wilson, C.F. Jenkins and L.A. Weaver, "U.S. IFYGL Precipitation Data Acquisition System," IFYGL Technical Manual No. 4, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, Washington, D.C., 1973, 48 pp.